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If a paper has not been seen in original it is safe to state 'Original not seen.'

Sources of information should be specifically acknowledged.

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Original articles—

Part IV. The effect of organic matter and lime on the erodibility of Dacca red loam.

Appendix. A method for measuring the dispersion ratio of Indian red and laterite soils.

I. The erodibility of some Bengal soils under bare field conditions

The field measurement of soil erosion has been carried out mostly in America. Excepting the works of Gorrie [1937; 1938] and that of Kanitkar, Daji and Gokhale [1941], no detailed record of measurement of erosion in the field is available in India.

Kanitkar, Daji and Gokhale [1941] conducted erosion experiments at Sholapur, Bombay. They studied the effect of intensity and distribution of annual rainfall on erosional behaviour of soils derived from the Deccan trap and belonging to the Chernozem group. The previous moisture status of the soil was found to influence the occurrence and extent of runoff very greatly. They also estimated the amount of soluble salts removed from soils in runoff, lime forming a considerable proportion of such losses.

Sir Archibald Geikie has mentioned in his Text-book of Geology the huge figure of 356.3 million tons of solid matter as being lost from the land by the Ganges during a single year.

The amount of rainfall lost as runoff has been measured by several workers. In America the work of Mosier and Gustafson [1918] over a period of three years shows that there is marked seasonal variation in percentage runoff which varies from 31 to 50 per cent of the annual rainfall. A runoff varying from 5 per cent in the case of plots covered with grass and shrub, to 25 per cent of a bare soil has been recorded by Gorrie [1938] in India. He further finds that nearly 8 tons per acre of soil are lost from a bare plot during a single monsoon. In Russia [Jacks and Whyte, 1938] the average soil losses vary from 20 tons per hectre per annum on gentle and moderate slopes to 50 tons on steep slopes. In Ceylon, Holland and Joachim [1933] observe that, under current estate practices, the soil loss by erosion varies from 56 to 101 tons per acre during a period of six years. Dickson [1929] has observed very heavy erosions with an average annual rainfall of only 21.68 inches. Lowdermilk [1931] finds a correlation between runoff and intensity of rainfall. On the other hand, Conner, Dickson, and Scoates [1930] have failed to establish any direct relation between erosion and intensity of rainfall. They observe, however, that runoff is influenced by the moisture content of the soil. Horton [1933] recognizes the importance of the moisture content of the soil and divides storms in two classes on the basis of their occurrence in relation to previous rains. Neal [1938] has shown that the moisture content of the soil at the time of precipitation is the most important factor determining the amount and rate of infiltration. As infiltration decreases runoff increases.

As regards the amount of nutrients removed in the process of soil erosion, Middleton [1932] observes that the severe result will be a loss of nitrogen, phosphorus and organic matter. According to Duley and Miller [1923] the losses in some cases are greater than the annual crop requirements.

The purpose of this paper is to obtain information regarding the relative erodibilities of some of the Bengal soils lying in the erosion-affected regions, and, incidentally, regarding the probable annual loss of soil material and fertility elements occurring in those soils when kept bare of vegetation. As the field measurement calls for elaborate arrangement which was beyond our means we were forced to adopt a simplified technique for measuring the erosion in small bare plots under short storms. Eight different places, distributed over Bengal, were selected. Two soils at each place had thus been examined. The results of the field measurement have been compared here with those obtained for the same soils in the laboratory under more controlled conditions (Part II of this series), so as to see if the latter could be exploited to advantage.

Experimental

A wooden bottomless box, 18 in. × 18 in. × 8 in., provided with 1 in. wide gutter along one side and 2 in. below the upper edge of the side, has been used for erosion measurement. The gutter is made slightly sloping to facilitate a free passage of the runoff along with the eroded soil in order to prevent the over-flow of the runoff which otherwise may be caused by the accumulation of the eroded material. An outlet tube kept flush with gutter is also provided.

A suitable open site is selected and carefully denuded of the natural vegetation (grass) by means of a flat trowel, disturbing the soil as little as possible. The slope of the land is then found out as follows: One end of a scale, 50 cm. long, is allowed to rest on the soil and the other end is slided up and down against another small scale held vertical, until a spirit level placed on the long scale indicates that the scale is horizontal. The vertical drop at this end of the scale is then directly read off from the small scale. This multiplied by 2 gives the per cent slope of the land.

At the site selected the box is placed and its inner boundary marked with a knife. The box is removed and the marked space is then completely covered with a metal plate. The object of the cover is to protect the surface soil from being disturbed during digging. With the cover kept in position, the ground around it is dug with a pick-axe to about the depth required for setting the box, care being taken that the pit so dug around the boundary is as narrow as possible. The box is placed in position and sunk by removing the extra earth from the sides with a '*Khanta*'. Where boulders appear as at Duars and Sukna and as they are likely to obstruct the sinking of the box, they are very carefully removed and the space is filled with the top soil; care being taken that when the box is sunk the gutter sets flush with the soil. The metal cover is then removed and any small gaps along the inner edges of the box are filled up with the top soil up to the surface level.

When the box has been fixed in position a bent glass tube is fitted through a hole at one end of the gutter by means of sealing wax. The other end of the bent tube is connected by a rubber tube with another glass tube leading through a rubber cork into a reservoir in which the runoff with the eroded material is collected. An air passage is provided for the reservoir by another glass tube through the rubber cork. All joints are then tested for leakage of water.

A rain gauge is placed nearby on land made level by scraping with the '*khanta*' and held firmly in position by means of wooden sticks fixed in the earth.

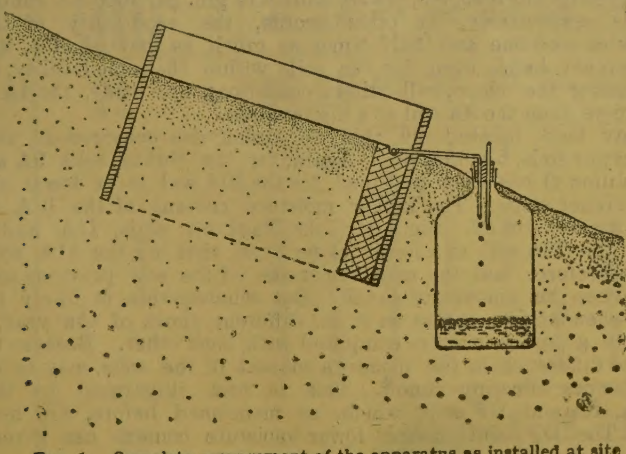

FIG. 1. Complete arrangement of the apparatus as installed at site

After the box has been installed, a few samples of the undisturbed soil are taken at random by a borer in the immediate neighbourhood outside the box to determine the moisture content before rainfall and the soil's mechanical composition.

After a shower, the eroded soil still left in the gutter is washed into the reservoir with a policeman, using a portion of the collected runoff by means of a pipette. The volume of the runoff is then measured and this along with the eroded soil is sent to the laboratory, where the eroded material is filtered, dried at 100—105°C. and weighed. The nitrogen in the eroded material is estimated by the modified Kjeldahl's method and the available phosphate by the Troug's method [Wright, 1939].

Effect of slope and soil characters

In Table I the rainfall, the runoff and the soil loss during experiment together with the name of the locality, soil number as well as its moisture content before rainfall, and other data are given.

All the soils, excepting 5A and 6A, show considerable erosion even under such light showers as 0.2—0.3 in. in some cases. Of the total precipitation received during experiment, 21 to 76 per cent of it has been lost as runoff (column h). The Durgapur (5A & 6A) soils, in which no runoff and soil-loss have occurred, are almost dry at the time of the experiment, and they have absorbed the whole of the shower of 0.45 in. as quickly as it has fallen. It will be further seen that the Bolpur (15A and 16A) soils are also similarly dry, and the amount and intensity of rainfall (columns c and e) are more or less identical with those in the case of Durgapur soils, yet there have occurred considerable runoff and soil losses (columns f and g). This difference in the erodibility between the Durgapur and Bolpur soils is partly due to the slope differences and partly to the difference in the mechanical composition of the soils of the two places. The Durgapur soils are highly sandy containing approximately 91 to 95 per cent sand, while the Bolpur soils are loamy containing about 35 to 40 per cent of clay plus silt (column k).

Comparative erodibility of the soils. If the soils, 2A, 8A, 10A and DF, the slopes of which are more or less equal are compared, it will be seen from columns (f) and (g) that both the runoff and soil loss of DF are very much greater than those of 2A, although the amounts of rainfall in the two cases are almost equal. The runoff and soil loss of 10A soil are minimum amongst the four soils compared. This, however, may be due to the much smaller precipitation in this case. In order, therefore, to bring the soil losses of all the soils on a comparative basis, the soil-loss in grams per 1000 c.c. runoff have been calculated and are given in column (j). It will be seen that the soil-losses in the case of the four soils are 5.29, 9.9, 12.98, and 18.19 gm. per 1000 c.c. runoff for 10A, 2A, 8A and DF soils respectively. In other words, the erodibility of the DF soil is roughly thrice, twice and one and half times as much as that of 10A, 2A and 8A respectively. On the other hand, even for the soils within the same locality, such as 3A and 4A, where, excepting the slope, all other conditions are same, the 4A soil at a lower slope has eroded more than the 3A soil at a higher slope.

It has already been pointed out that no runoff has occurred in the case of the almost dry Durgapur soils, 5A and 6A. Again, for the Sukna soils 9A and 10A, much greater runoff (column f) has been obtained for the 10A soil at a lower slope than that of 9A soil at a higher slope. The higher moisture content of the 10A soil may have partly caused a greater runoff. Similarly, the Bankura soils, 11A and 12A, show a greater runoff for the 12A soil at a lower slope than that for the 11A soil at a higher slope. It seems, therefore, that the moisture status of the soil previous to a storm may considerably influence the amount of runoff. But whereas this is likely to be apparent for any one soil when erosion occurs in it at different times of the year, this may not be evident when a group of soils are compared with each other. Because the differences, if any, due to the difference in the moisture content of the soils, may be masked by the effects of other factors affecting runoff. This is best illustrated by the runoff per cent again, of 2A, 8A and DF soils which, as mentioned before, are more or less at the same slope. The DF soil with a lower moisture content has given more runoff

TABLE I

Rainfall, runoff and soil losses

Soil No.	Locality	Slope p. c.	Moisture content before rainfall p. c.	Rainfall in inches	Duration of rainfall	Rainfall in inches per hour	Runoff in c.c.	Soil loss in gm.	Runoff per cent	Soil loss in gm. per in. rain	Soil loss in gm. per 1000 c.c. runoff	Clay and Silt (mechanical analysis) p. c.
		a	b	c	d	e	f	g	h	i	j	k
1A	Jyadebpur (Dacca) ...	15.0	14.12	0.81	50 min.	0.97	1692	28.25	39.35	34.87	16.6	50.5
2A		5.0	10.43				1225	12.20	28.49	15.06	9.9	53.2
3A	Agartola (Tippera) ...	16.1	20.71	1.84	1 hr. 40 min.	1.09	4275	151.44	43.79	82.30	35.42	49.3
4A		12.5	25.63				3685	156.90	37.75	85.27	42.57	42.5
5A	Durgapur (Mymensingh) ...	8.2	1.90	0.45	34 min.	0.79	...	...	...	...	...	5.1
6A		4.5	3.70				...	...	...	...	...	8.8
7A	Duars (Jalpaiguri) ...	8.7	33.20	1.32	31 min.	2.56	2835	58.01	40.46	43.94	20.46	42.8
8A		5.0	30.17				2515	32.65	35.89	24.73	12.98	50.9
9A	Sukna (Darjeeling) ...	20.2	23.90	0.25	22 min.	0.67	390	6.02	28.64	24.08	15.43	47.0
10A		4.8	28.50				590	3.12	44.45	12.48	5.29	56.6
11A	Bankura ...	12.9	22.31	0.21	16 min.	0.76	695	10.85	62.31	51.66	15.61	19.7
12A		3.7	36.40				850	6.26	76.26	29.80	7.36	45.6
15A	Bolpur (Birbhum) ...	10.1	3.6	0.45	33 min.	0.81	760	10.98	31.79	24.40	14.44	35.8
16A		11.6	4.1				925	14.72	56.46	32.71	15.91	39.4
DH	Dacca Hall (Dacca) ...	21.3	...	0.63	Occasional, 7 days	...	1020	12.28	30.47	19 50	12.04	49.3
			...	0.25	Do. 5 days	..	300	9.89	21.11	39.56	32.96	49.3
DF	Dacca Farm (Dacca) ...	6.5	6.21	0.86	Do. 5 days	...	2175	39.56	45.48	45.90	18.19	48.5

than either the 2A or the 8A soil, although the precipitation in the case of the 2A or the 8A soil is either equal to, or heavier than that in the case of the DF soil.

From all that has been stated above it appears that the erosion of the soils examined is considerably influenced in addition to the slope and the previous moisture-status by the properties of the soils themselves. It would be interesting, therefore, to study from a comparative point of view the extent to which these properties collectively influence erosion of the soils under more controlled conditions, and also to find out those properties that are more responsible in causing runoff and erosion. These two studies have been taken up in Parts II and III respectively.

Comparison of field and laboratory measurements

In Part II the erosion measurements have been made in the laboratory with soils packed in boxes of the same dimensions as those used in the field measurement. Here the amount, intensity and the duration of rainfall as well as the slope are controlled. The figures thus obtained certainly offer a much better comparison of the erodibility of the soils. However, it would be interesting to see to what extent the laboratory measurement reflects the erosion taking place under field conditions. In Table II the average soil-losses in grams per 1000 c.c. runoff obtained at various slopes by laboratory measurement are compared with those obtained in the field already reported in this part.

TABLE II

Soil losses in field and laboratory measurements

Soil No.	Slope p. c. (Field) v	Rainfall in inches (Field) w	Soil loss in gm. per 1000 c. c. runoff: (Field data) x	(Laboratory data) y	Slope p. c. (Laboratory) z
1A	15.0	0.81	16.6	27.6	15.0
2A	5.0		9.9	20.2	5.0
3A	16.1	1.84	35.4	28.0	15.0
4A	12.5		42.6	27.0	12.5
7A	8.7	1.32	20.5	18.7	8.7
8A	5.0		13.0	9.8	5.0
9A	20.2	0.25	15.4	45.5	20.0
10A	4.8		5.3	23.1	5.0
11A	12.9	0.21	15.6	23.8	12.5
12A	3.7		7.4	13.5	5.0
15A	10.1	0.45	14.4	21.7	10.0
16A	11.6		16.0	20.0	10.0
DH	21.3	{0.63 {0.25	12.0 33.0	53.1	20.0
DF	6.5	0.86	18.2	26.3	5.0

The laboratory measurement of erosion has been carried out under 1 in. of rainfall and the soil loss given in column (y) of the above table is obtained from the average soil loss figure of three successive inches of rain at the respective slope. It will be seen from the table that where the amount of rainfall in the field has been more than one inch, for example, 3A and 4A, the soil losses are greater than those obtained in the laboratory. Where the rainfal has been approximately 1 in. as in 7A and 8A, the soil losses are more or less equal to those obtained in the laboratory. And where it has been smaller than one inch, as in most of the remaining cases, the laboratory measurement gives higher values in soil losses. It appears, therefore, that under similar rainfall the results of laboratory and field measurements are also similar. The laboratory measurement can thus be employed with advantage to get an approximate idea of the extent of erosion occurring in the field. The importance of this is obvious. The technique usually employed in measuring the erosion in the field is not only very costly but it also fails to give an absolute measure of the erosion which varies from year to year depending upon the amount, intensity and distribution of annual rainfall. Thus the field measurement can only be approximate and is as defective as the laboratory measurement possibly is. Besides, the field measurement is of limited applicability, since the results for a particular plot will apply for that plot only and will not be applicable to a soil, not far away, due to variation in slope, physical property and other factors. Laboratory measurement, on the other hand, although possessing the same inherent defects as in the field measurement, has a considerable economic advantage over the latter and can be employed with greater success by carrying out the measurement on a large number of soils in the neighbourhood with practically very little additional cost.

The loss of fertility elements. Although the field measurement employed here is of a very preliminary nature, nevertheless, it gives an approximate idea of the possible extent of erosion which these soils are likely to suffer annually when put under cultivation without erosion-control measures. The soil loss in tons per acre per inch rain has been calculated from the figures in column (i) of Table I, and are given in Table III together with the annual precipitation, the run off per cent of column (h) of Table I, the percentage of nitrogen and P_2O_5 in the eroded material, etc.

TABLE III

The annual runoff and loss of soil and fertility elements

Soil No.	Annual precipitation in inches (approx.)	Runoff per cent	Soil-loss in tons per acre per inch rain	Annual runoff in inches	Annual soil-loss in tons per acre	Nutrients in eroded material: Total N p. c.	Nutrients in eroded material: Available P_2O_5 p. c.	Annual loss of nutrients in eroded material per acre in lb.: Total N	Annual loss of nutrients in eroded material per acre in lb.: Available P_2O_5
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1A	68	39·4	0·69	26·8	47·0	0·15	0·004	157·5	4·2
2A		28·5	0·30	19·4	20·4	0.27	0·005	123·4	2·3
3A	72	43·8	1·64	31·5	116·6	0.38	0·006	992·5	15·7
4A		37·8	1·71	27·2	123·1	0·29	0·006	799·7	16·5
7A	196	40·5	0·87	79·3	170·5	0·81	0·007	3093·6	26·7
8A		35·9	0·49	70·3	96·0	0·84	0·008	1806·3	17·2
9A	150	28·6	0·48	43·0	72·0	0·99	0·007	1596·7	11·3
10A		44·5	0·25	66·7	37·5	0·87	0·006	730·8	5·04
11A	55	62·3	1·03	34·3	56·7	0·32	0·005	406·4	6·4
12A		76·3	0·59	42·0	32·5	0·29	0·005	211·1	3·6
15A	57	31·8	0·48	18·1	27·4	0·12	0·004	73·7	2·5
16A		56·5	0·65	52·2	37·1	0·25	0·005	207·8	4·2
DH	70	80·5	0·39	21·3	27·3				
		21·1	0·79	14·8	55·3				
DF	70	45·5	0·91	31·8	63·7	0·75	0·005	1070·2	7·3

It will be seen from Table III that the annual precipitation in the areas examined varies from 55 to 200 in. (column 2). All of this rain will not cause erosion but the bulk of it will. If, however, we assume that the whole of the rain will be effective in the same way as the observed shower in the field measurement, the probable annual runoff may be as much as 14.8—79.3 inches (column 5) and the annual soil loss as much as 20—170 tons per acre (column 6). This soil loss certainly occurs from the top, the most fertile portion of the soil. The magnitude of this loss and its consequent effect on crop growth may be further realized from the annual loss of total nitrogen and available P_2O_5 in the eroded material which may be as much as 74—3094 lb. and 2.3—26.7 lb. per acre respectively (columns 9 and 10).

Summary

1. In order to gain some information of the relative erodibilities of Bengal soils field measurement of erosion has been made in small bare plots under short storms at eight different places distributed over Bengal, where erosion in the cultivated fields does occur. Two soils at each place have been examined.

2. All the soils investigated are found to be fairly erosive. As much as 21—76 per cent of the precipitation may escape as runoff and as much as 20—170 tons of soils may be eroded annually carrying with it 74—3094 lb. of total nitrogen and 2.3—26.7 lb. of available P_2O_5 approximately.

3. The moisture-status of a soil previous to a storm considerably influences the runoff.

4. The soils at more or less the same slope are found to erode very differently, one eroding 1½ to 3 times as much as others. Furthermore, a soil at a lower slope is found to erode more than an adjacent soil at a higher slope.

5. Therefore, it is proposed to study further the relative erodibilities under more controlled conditions in the laboratory. The merits of the laboratory and field measurements are also discussed.

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PLANT-FOOD REQUIREMENTS OF CALCAREOUS SOILS

I. OPTIMUM REQUIREMENTS OF PHOSPHORUS FOR PUSA CALCAREOUS SOILS

By S. Das, M.Sc. (Cal. and Alld.), D.Sc. (Alld.) Assistant Agricultural Chemist, Imperial Agricultural Research Institute, New Delhi

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(With two text-figures)

Since the beginning of agricultural research, the problem of determining plant-food requirements of a soil has been of major importance. Various methods of solving this problem have been proposed, including a complete analysis of the soil, extraction by acids of various kinds and strengths as well as by physiological means. It must be admitted, however, that at the present time there is no known method which is both accurate and universally applicable.

The fact that the proposed methods are all empirical in character is a great drawback, but the serious objection is that the results give a measure of the condition of a soil at a particular time only and obviously cannot apply to its condition at different times throughout the year. There is probably no hard-and-fast line between the 'non-available' and the 'available' constituents, the one set gradually merging into the other.

The whole question of available plant food is necessarily bound up with the complex relationship that exists between plant and soil, and it is unlikely that any simple or single method will be devised to overcome the inherent difficulties attaching to the problem and be generally applicable to different sets of conditions. The admitted lack of agreement obtained with the various methods at present in use is undoubtedly due, to a large extent, to the variety of factors involved as well as to the fundamental objections which may be raised to any one method. We are still very ignorant of the process of assimilation by the growing plant, and until we have more information on this subject, methods of estimating available plant food in soils must continue to be largely empirical and the results merely first approximations.

The belief of the practical agriculturist that the chemist can give reliable advice purely as a result of analysis of his soil, dies hard ; it is still a common experience to receive a sample of a few ounces of soil with a request for detailed recommendations as to the manuring of the land in question. Now-a-days no agricultural chemist of repute would be so bold as to make such recommendations merely on the basis of a soil analysis. He knows that plant food supply is only one of the many factors which may exert a dominant influence on crop production. Detailed knowledge of climate, drainage, method of cropping, and so forth, must be available. Given such information, soil analysis can be of great value, but the final test must always consist of actual manurial trials on the land. For the plant must be accepted as the ultimate criterion and all conclusions drawn according to plant response.

It is well known that the growing plant itself possesses power to a greater or less degree to feed directly on phosphates and that some plants possess specially marked powers [Truog, 1916]. As a result, no common limiting value for available phosphoric acid can be suggested, as given by Dyer [1894], which will be equally applicable for all types of soil. Consequently, this value must be worked out for different soils. Even in the same soil it will be different according to the types of crop grown on it from time to time, as crops vary greatly in feeding power and phosphate requirement. There is, therefore, a need for studying these two properties for various crops.

The problem becomes further complicated by the fact that different types of soil

require different systems of manuring. Although calcareous soils round about Pusa belonging to the Indo-Gangetic alluvium and containing 30 to 40 per cent of chalk, yield extremely low values of available phosphoric acid when measured by the ordinary laboratory methods, the action of phosphatic fertilizers on them in actual farm practice is extremely erratic. As for instance, the application of superphosphate alone, more often than not, yields disappointing results, and the best results are usually obtained when applied in conjunction with heavy organic manures.

Earlier work of this laboratory lays stress on the following three factors for this uncertain action of superphosphate in calcareous soils, viz.:

1. The retention of soluble phosphoric acid of superphosphate in the surface layers as insoluble calcium phosphates by chemical combination with the large amount of calcium carbonate normally present in these soils and the consequent localized action of superphosphate as shown by Harrison and Das [1921];

2. the depressing action on the cropping power of calcareous soils of gypsum which is present to the extent of 50 to 60 per cent in commercial superphosphate as shown by the author [Das, 1933]; and

3. the deleterious effect of the surface application on the availability of superphosphate in calcareous soils as recently demonstrated by the author [Das, 1945].

The depressing effect of the factors (1) ond (3) can be successfully counteracted by applying superphosphate 4 to 6 inches deep, which has been shown by the author [Das, 1945] to bring about the maximum crop production in calcareous soils.

As laboratory methods alone fell far short of expectations in finding optimum plant food requirements of soils, it was considered desirable to discover the same by actual manurial trials on the land.

Experimental

Two series of pot experiments were instituted in 1933 with a calcareous Pusa soil containing 33 per cent of calcium carbonate. Four pots of similar dimensions, viz. 9 in. in diameter and 12 in. high formed a group and received similar treatment. In one series nitrogen and potash were added as a basal dressing to all the pots at the rate of 60 lb. per acre as sulphate of ammonium and potassium chloride respectively. P_2O_5 as precipitated calcium phosphate was added to different groups of pots at the rate of 25, 50, 75, 100, 200 and 400 lb. per acre, which correspond respectively to 0.00125, 0.0025, 0.00375, 0.005, 0.01, and 0.02 gm. P_2O_5 per 100 gm. of soil. In the other series nitrogen was supplied as a basal dressing to all the pots at the same rate as in the first series in the form of dried leaves of sunn-hemp (*Crotalaria juncea*). The dried green manure added contained potash equivalent to 80 lb. per acre and P_2O_5 equivalent to 25 lb. per acre. Allowance was made for the latter while adding increasing amounts of precipitated calcium phosphate to supply P_2O_5 to different groups of pots as in the first series. Each pot contained 15 kilos of air-dry soil. The pots were watered from the top and 16 per cent of moisture was maintained in the soil throughout the expriment. The maximum water-holding capacity of the soil was 48 per cent. There was a group of control pots in each series for comparison where no phosphate was added, but nitrogen and potash were supplied as a basal dressing. *Ragi* (*Eleusine coracana*) was sown on 16 June and the crop harvested on 10 October 1933. Although the weights of both grain and straw per pot were recorded separately, only the mean yields of grain are given in Table I along with their statistical examination by Fisher's [1932] analysis of variance.

TABLE I

The mean yields of ragi (Eleusine coracana) *grain in Pusa calcareous soil with increasing doses of calcium phosphate*

P_2O_5 per acre in lb.	A Series with N as $(NH_4)_2SO_4$		B Series with N as dried sunn-hemp leaves	
	Mean yield in gm.	Percentage of increase over control	Mean yield in gm.	Percentage of increase over control
Control	11.60	—	11.88	—
25	19.33	66.4	16.10	35.3
50	20.18	74.1	20.23	70.0
75	25.95	123.7	26.20	120.2
100	26.88	140.5	27.80	133.6
200	23.98	106.8	25.63	115.7
400	28.38	144.7	26.95	126.9
Standard error for comparison of mean yields ...	1.33		2.03	
Critical difference for 1 per cent ...	3.77		5.75	
Critical difference for 5 per cent ...	2.77		4.22	

From Table I it is evident that the differences in mean yields of *ragi* grain between the control and every other treatment in both the series are highly significant, being greater than the critical value of difference even for one per cent level of significance. Similar differences of other treatments over either 25 or 50 lb. P_2O_5 per acre are also highly significant, but among 25 and 50 lb. of P_2O_5 themselves, or among the remaining treatments no significance in mean yields of grain is found. The application of 75 lb. of P_2O_5 per acre yields practically the maximum crop production, although higher applications of P_2O_5 appear to give slightly better crop returns which are not, however, significant at all. Consequently, the application of 75 lb. of P_2O_5 per acre meets the optimum phosphate requirements of calcareous soils here for a *kharif* (summer) crop like *ragi*.

Another striking fact noticed is that green manure applied to soils in the dry state as in the present instance does not prove better than ammonium sulphate, when applied to supply nitrogen. This may be attributed to the fact that most of the advantages accruing from the process of fermentation of green plant materials are lost, while using the same in a dried form.

Next it was considered desirable to discover any relationship that might exist between the available phosphoric acid determined by ordinary laboratory methods of the soils treated with increasing doses of the phosphatic fertilizer and the corresponding crop yields. For this purpose soil samples from the differently treated pots of both A and B series of experiments were examined for available phosphoric acid by Dyer's [1894] citric acid method as well as by the potassium carbonate method of the author [Das, 1926]. The results obtained are set forth in Table II along with the mean yields of *ragi* reproduced from Table I for comparison.

TABLE II

Available phosphate of soil samples of pots treated with increasing doses of phosphatic fertilizer and the corresponding crop yields

P_2O_5 added per acre in lb.	Control	25	50	75	100	200	400
P_2O_5 added per 100 gm. of soil in gm.	*nil*	0.00125	0.0025	0.00375	0.005	0.01	0.02
A Series. With N as ammonium sulphate							
Percentage of P_2O_5 by K_2CO_3	0.0028	0.0037	0.0053	0.0056	0.0059	0.0092	0.0157
Percentage of P_2O_5 by citric acid	0.0009	0.0009	0.0009	0.0010	0.0011	0.0019	0.0029
Mean yield of *ragi* in gm.	11.60	19.33	20.18	25.95	26.88	823.98	2[illegible].3
B Series. With N as dried sunn-hemp							
Percentage of P_2O_5 by K_2CO_3	0.0032	0.0035	0.0039	0.0046	0.0051	0.0086	0.0161
Percentage of P_2O_5 by citric acid	0.0009	0.0011	0.0014	0.0015	0.0016	0.0018	0.0041
Mean yield of *ragi* in gm.	11.88	16.10	20.23	26.20	27.80	25.63	26.95

The above results are graphically represented in Figs. 1 and 2.

It is evident that the values of available phosphoric acid by the citric acid method are extremely low up to the application of 100 lb. of P_2O_5 per acre in both the series of experiments. Besides, they offer such great manipulative difficulties in their estimation as to render their accuracy hardly reliable. On the other hand, the potassium carbonate method gives values of available phosphoric acid which show a fair increase with gradually higher applications of P_2O_5 and are significantly related to the corresponding crop yields up to the limit of 75 lb. of P_2O_5 per acre. Taking the average of both the series which are similar experimental conditions, it is noticed that 0.005 per cent of available phosphoric acid meets the optimum phosphate requirements of calcareous soils and produces the maximum crop yield. Although higher applications of P_2O_5 per acre undoubtedly increase considerably the values of available phosphate either by the citric acid or the potassium carbonate method, a correspondingly high increase in crop yields is not secured. Higher values of available phosphate may be attributed to the effect of mass action only.

Therefore, it may be concluded that the value of 0.005 per cent of available phosphoric acid as determined by the potassium carbonate method resulting from the application of 75 lb. of P_2O_5 per acre meets the optimum phosphate requirements of the Pusa calcareous soils for maximum crop production.

In order to obtain further confirmation pot experiments were repeated in 1933 and 1934 with mustard and oats respectively. Pots and other working details were the same as in the case of the previous pot experiments with *ragi*.

Mustard was sown on 11 November, 1933 and the crop harvested on 9 March, 1934. Oats were sown on 3 November, 1934 and the crop was harvested on 19 March, 1935. The mean yields of mustard and oats are given in Table III.

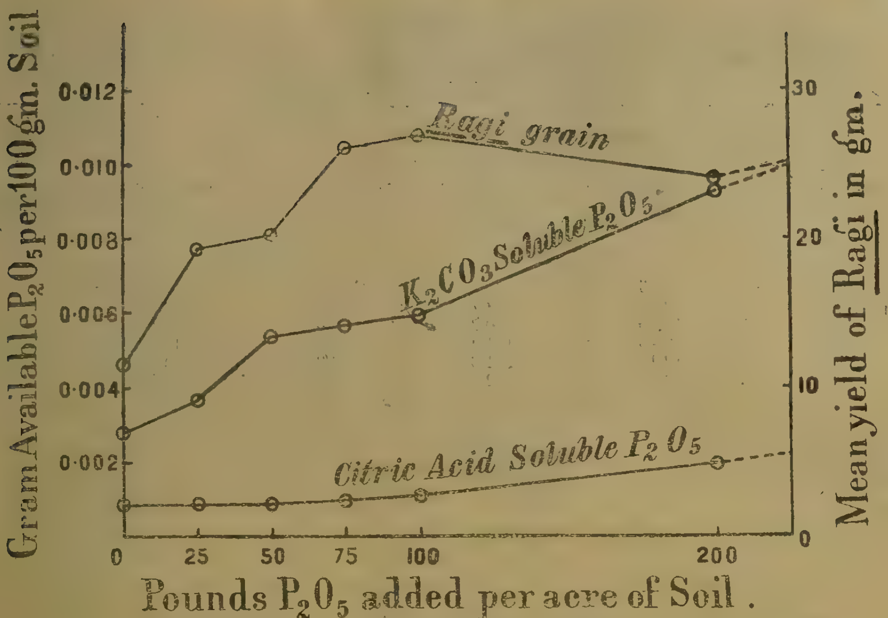

FIG. 1. A Series

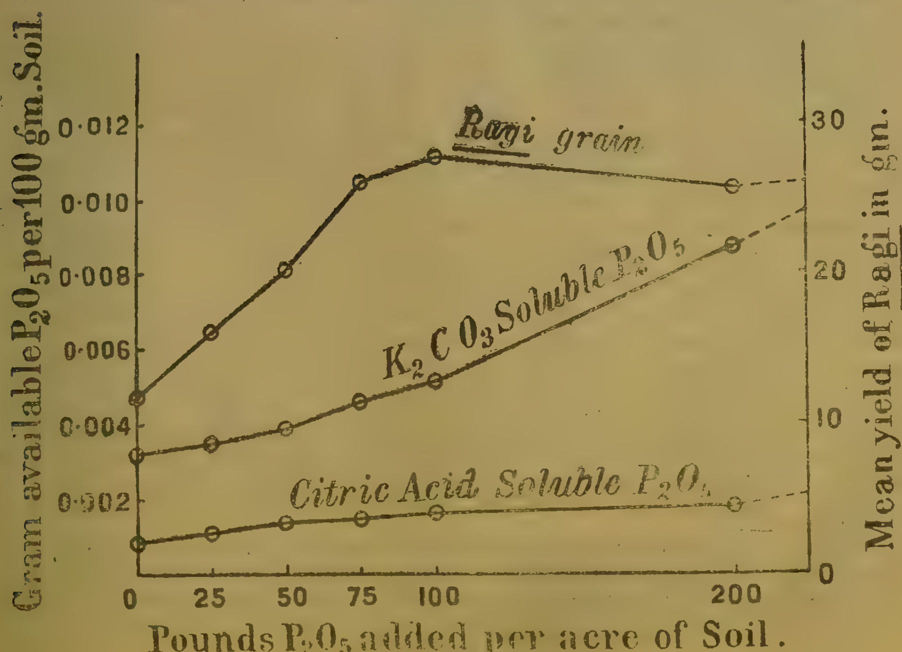

FIG. 2. B Series

FIGS. 1 and 2. The graphical representations for the comparison of the available phosphate of soils under increasing doses of the phosphatic fertiliser with the corresponding crop yields of A and B series of pot experiments respectively

TABLE III

Mean yields of mustard and oats grain in Pusa calcareous soil with increasing doses of calcium phosphate

	Mustard 1933-34			Oats 1934-35	
P_2O_5 per acre in lb.	Mean yield in gm.	Percentage of increase over control	P_2O_5 per acre in lb.	Mean yield in gm.	Percentage of increase over control
Control	6.05	—	Control	30.10	—
60	10.45	72.7	50	107.00	255.5
70	10.93	80.7	60	120.43	300.1
80	13.40	121.4	70	113.90	278.4
90	12.18	101.3	80	112.53	273.8
100	9.85	62.8	100	115.60	284.0
Standard error for comparison of mean yields ...	1.255			4.83	
Critical difference					
For 1 per cent	3.61			13.90	
For 5 per cent	2.64			10.15	

From Table III it is evident that the application of 80 and 60 lb. of P_2O_5 per acre gives the maximum yields of mustard and oats respectively, and meets the optimum phosphate requirements of calcareous soils for these crops.

Therefore, the four series of pot experiments detailed above indicate that the application of 60, 75 and 80 lb. of P_2O_5 per acre meets the optimum phosphate requirements of calcareous soils for oats, *ragi* and mustard respectively.

In order further to test these conclusions arrived at from pot experiments, field trials in the Punjab Experimental Area of the Pusa Farm were undertaken in 1934 in three adjacent $\frac{1}{4}$ acre plots, each of which was subdivided into 18 equal sub-plots of $\frac{1}{72}$ acre each measuring about 30 ft. north to south and 20 ft. east to west. A basal dressing of potash and nitrogen at the rate of 60 lb. per acre as potassium chloride and ammonium sulphate respectively was given to all the sub-plots and phosphate as superphosphate applied 4 inches below the surface soil by deep ploughing to the plots concerned. There were six treatments of nine replications each.

The treatments were P_0, P_1, P_2, P_3, P_4 and P_5 representing respectively control with nitrogen and potash only but no phosphate, and 50, 70, 80, 90 and 100 lb. of P_2O_5 per acre besides the basal dressings of nitrogen and potash as in the control plots.

Ragi seedlings grown outside and about three weeks old were transplanted on 11 July 1934 in 31 lines one foot apart with 39 plants in each placed six inches apart. A fortnight after transplanting, *ragi* seedlings were dying at places; these were replaced by fresh ones grown outside. Plants progressed well and during harvest one line from the surrounding border of each sub-plot was rejected, thus leaving 29 lines with 37 plants in each. On 9 September *ragi* plants from the border were cut off and rejected, and ripe cobs collected on 11 and 22 September, 1934. This interval was given on account of unequal ripening.

Next a crop of oats was raised in these very plots in the following winter of 1934 in order to study the residual effect of the fertilizers. Oats were sown on 3 November 1934, and the crop was harvested on 23 March 1935. Mean yields of *ragi* and oats grain are given in Table IV.

TABLE IV

Mean yields of ragi *and oat grain in field experiments with Pusa calcareous soil under increasing doses of a phosphatic fertilizer*

P_2O_5 per acre in lb.	Primary effect		Residual effect	
	Ragi 1934		Oats 1934-35	
	Mean yield in lb.	Percentage of increase over control	Mean yield in lb.	Percentage of increase over control
P_0=Control ...	22.76	—	8.77	—
P_1= 50 ...	25.04	10.0	9.09	3.7
P_2= 70 ..	25.84	13.2	9.26	5.6
P_3= 80 ...	25.87	13.7	9.43	7.5
P_4= 90 ...	26.21	15.2	10.38	18.4
P_5=100 ...	25.37	11.5	8.98	2.4
Standard error for comparison of mean yields ...	1.00		0.607	
Critical difference				
For 1 per cent ...	2.69		1.64	
For 5 per cent ...	2.02		1.22	

From Table IV it is evident that the differences in mean yields of *ragi* grain between the control and every other treatment are significant, being greater than the critical value of difference for 1 per cent level of significance in all cases except 50 and 100 lb. of P_2O_5 per acre where 5 per cent level of significance holds. Thus, of the treatments showing 1 per cent level of significance, the application of 70 lb. of P_2O_5 per acre produces the maximum crop yield from the farmer's point of view, although 80 and 90 lb. of P_2O_5 give slightly better returns which were not, however, significant at all. With regard to the oat crop no phosphatic treatment has any residual effect except the original treatment of 90 lb. of P_2O_5 per acre.

It will thus be evident that the application of 70 lb. of P_2O_5 per acre on a field scale can satisfactorily meet the optimum phosphate requirements of calcareous soils for a *kharif* crop like *ragi*. It is interesting to note that this limit is not very different from the optimum dose of 75 lb. of P_2O_5 found in the case of pot experiments.

Next it was thought worthwhile to get an idea of the practical value of the manurial requirements of these soils, as the farmer would like to know what return he could expect from manuring these soils. For this purpose, the economics of the manurial treatment may be taken into account. From the cropping experiments detailed above it was found on calculation that by spending about Rs. 8 to 10 extra as the cost of adding per acre about 80 to 100 lb. of P_2O_5 as superphosphate according to the optimum phosphate requirements of various crops in these calcareous soils, enough extra yields of *ragi*, mustard, and oats over the control were obtained which justified the manurial treatment by leaving a decent margin of profit. The residual effect of 60 lb. of P_2O_5 was, however, found not to be economically significant.

It was then of interest to know the rate of assimilation of important food materials by the growing crop from the fertilizers applied. For this purpose, the representative samples of *ragi* grain collected from the nine replicated sub-plots of each treatment were submitted to chemical analysis and the results obtained are given in Table V.

TABLE V

The chemical composition of ragi *grain grown in field experiments with Pusa calcareous soil under increasing doses of a phosphatic fertilizer*

P_2O_5 per acre in lb.	Per cent constituents calculated on dry *ragi* grain					Mean yield of grain in lb. per plot
	Ash	Sand	K_2O	N	P_2O_5	
P_0 = Control ...	3.32	0.16	0.861	1.53	0.498	22.76
P_1 = 50 ...	3.21	0.21	0.792	1.56	0.506	25.04
P_2 = 70 ...	3.15	0.16	0.802	1.50	0.543	25.84
P_3 = 80 ...	3.09	0.21	0.819	1.42	0.600	25.87
P_4 = 90 ...	2.96	0.14	0.724	1.47	0.642	26.21
P_5 = 100 ...	3.09	0.14	0.809	1.46	0.609	25.37

It is seen that the P_2O_5 content of the *ragi* grain increases appreciably with the increased applications of the phosphatic fertilizer, while the nitrogen content tends to decrease slightly. Its potash content, however, does not exhibit any appreciable variation.

SUMMARY

1. Pot and field experiments substantially confirm the conclusion that the application of 60, 70 and 80 lb. of P_2O_5 per acre with basal dressings of nitrogen and potash yields the maximum crop of oats, *ragi*, and mustard respectively in Pusa calcareous soils and meets the optimum requirements of these soils for the above crops.

The cropping results were both statistically and economically tested and found to be highly significant.

2. The examination of the available phosphate of the soil samples showed that the values obtained with the author's potassium carbonate method were significantly related to the crop yields of *ragi* up to the limit of 75 lb. of P_2O_5 per acre. Hence, 0.005 per cent of available phosphoric acid of a calcareous soil resulting from the application of 75 lb. of P_2O_5 per acre corresponds to the maximum crop production.

3. On the other hand, the values of available phosphate obtained with the Dyer's citric acid method did not yeild such significant results as above and failed to corroborate the results of the crop yields.

4. The examination of the rate of assimilation of important food materials by the growing crop from the soil and the applied fertilizers showed that the P_2O_5 content of the *ragi* grain increases appreciably with the increased applications of the phosphatic fertilizer, while the nitrogen content tends to decrease slightly. Its potash content, however, does not show any appreciable variation.

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PLANT-FOOD REQUIREMENTS OF CALCAREOUS SOILS

II. OPTIMUM REQUIREMENTS OF NITROGEN FOR PUSA CALCAREOUS SOILS

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(With Plate XXI)

Nitrogen is by far the most important of the principal plant-food materials in which Indian soils are usually deficient. The manurial problem is, therefore, in the main, one of nitrogen deficiency in India. Calcareous soils in the Indo-Gangetic alluvium in Bihar respond well to all types of nitrogenous fertilizers. Oil cakes are available in plenty in this part of the country where the practice of green manuring is also well-known. Further, artificial fertilizers like ammonium sulphate, sodium nitrate, ammonium phosphate, etc. are gradually finding greater application in agricultural practice here. Information on the optimum requirements of nitrogen for proper crop production in these soils is however lacking. As oil cakes are easily available nitrogenous manures commonly used in farm practice here, their action for the supply of nitrogen to these calcareous soils was first studied.

Experimental

A sample of apricot seed cake on which some experiments were carried out in this laboratory by the author [Das, 1945] to find its use as a nitrogenous manure, was selected for the present inquiry. Biochemical studies demonstrated that 63 per cent of nitrogen contained in the cake could be transformed into available forms in Pusa calcareous soils in eight weeks and that further incubation did not increase the available nitrogen in the soil mixture. Next it became of interest to determine how much of the cake would meet the optimum requirements of nitrogen for maximum crop production in these calcareous soils. As the cake with 6.7 per cent of nitrogen contains also 1.49 per cent of P_2O_5 and 1.09 per cent of potash, extra doses of these two constituents were not applied as fertilizers in the following pot experiments.

A series of pot experiments was started in the winter of 1932 with the Pusa calcareous soil containing about 35 per cent of calcium carbonate. Wheat was chosen as the *rabi* (winter) crop which responds readily to nitrogenous manures. Four pots of similar dimensions, viz. 9 in. diameter by 12 in. high formed a group and received similar treatment. The pots contained 15 kilos of air-dry soil in each and 16 per cent of moisture was maintained in the soil throughout the experiment. There was a group of control pots where no cake was applied. After the wheat crop was harvested, a second crop of *ragi* (*Eleusine coracana*) was raised in the following summer of 1933 in these pots without any further manurial treatment in order to determine the residual effect of the cake. The cake was applied to the pots according to the scheme shown in Table I.

TABLE I

The scheme of the application of the oil cake to pot culture experiments

Pot numbers	Nitrogen from the cake per kilo of soil in mg.	Manurial constituents per acre of soil from the cake in lb.		
		N (Based on 63 per cent availability)	P_2O_5	K_2O
1 to 4	Control	—	—	—
5 to 8	10	12.6	4.47	3.27
9 to 12	20	25.2	8.94	6.54
13 to 16	40	50.4	17.88	13.08
17 to 20	50	63.0	22.35	16.35

Wheat seeds were sown on 10 November, 1932 and the crop was harvested on 20 March, 1933. After the harvest of wheat-crop was over, *ragi* seeds were sown in these very pots in the next season on 11 June, 1933 to study the residual effect of the cake. The *ragi* crop was harvested on 3 October, 1933. Mean yields of grain of both the crops are given in Table II along with their statistical examination by Fisher's [1932] analysis of variance.

TABLE II

The primary and the residual effect of apricot seed cake on the yields of wheat and ragi *respectively in Pusa calcareous soil*

Nitrogen per acre of soil in lb.	Primary effect with wheat		Residual effect with *ragi*	
	Mean yield in gm.	Percentage of increase over control	Mean yield in gm.	Percentage of increase over control
Control	4.34	—	9.08	—
20	8.01	84.6	10.63	17.1
40	8.26	90.4	10.13	11.6
80	10.08	132.3	10.55	16.2
100	11.06	155.0	12.20	34.4
Standard error for comparison of mean yields	0.59		0.98	
Critical difference				
For 1 per cent	1.74		2.89	
For 5 per cent	1.26		2.09	

It is seen that the increase in the yield of wheat over the control is high according to the increasing doses of the manure applied and that the differences in mean yields of grain between the control and every other treatment are highly significant being greater than the critical value of difference for 1 per cent level of significance. The maximum crop was practically obtained by the application of 80 lb. of nitrogen per acre as cake, although a little better crop was produced by 100 lb. of nitrogen per acre which was not however significant.

In the case of *ragi*, although the increase in the yield of grain over the control indicated the residual effect of every treatment of the cake, 100 lb. of nitrogen only gave significantly higher yield than the control. It may therefore be concluded that the residual effect of the cake can persist till the next succeeding crop in calcareous soils, only when it is initially applied to the land at the rate of 100 lb. of nitrogen per acre.

Next, cropping experiments both in pots and fields were instituted in the winter of 1934 to see how much of an artificial nitrogenous fertilizer like ammonium sulphate was needed to meet the optimum requirements of nitrogen for proper crop production in calcareous soils.

Similar pots as in the case of pot experiments with cake were used and similar procedure was followed. Basal dressings of potash and phosphoric acid at the rate of 80 lb. and 100 lb. per acre as potassium chloride and superphosphate respectively were given to all the pots. There was a group of control pots for comparison, where potash and phosphate were added but no ammonium sulphate. Wheat seeds were sown on 28 October, 1934 and the crop was harvested on 14 March, 1935. Mean yields of grain are presented in Table III along with their statistical examination by Fisher's [1932] analysis of variance.

TABLE III

Mean yields of wheat in Pusa calcareous soil under increasing doses of ammonium sulphate

Nitrogen per acre of soil in lb.	Mean yield in gm.	Percentage of increase over control
Control ...	25.20	—
40 ...	32.40	28.6
60 ...	36.05	43.1
70 ...	36.18	43.7
80 ...	31.53	25.1
100 ...	27.20	8.0

Standard error for comparison of mean yields ...	1.557
Critical difference	
For 1 per cent ...	4.48
For 5 per cent ...	3.27

It is seen that the increase in the yield of grain is high over the control with every treatment of ammonium sulphate except 100 lb. of nitrogen per acre and that the differences in mean yields of grain between the control and every other treatment except 100 lb. of nitrogen per acre are highly significant being greater than the critical value of difference even for 1 per cent level of significance. The maximum crop was practically obtained by the application of 60 lb. of nitrogen per acre. Therefore it may be concluded that the application of 60 lb. of nitrogen per acre as ammonium sulphate meets the optimum requirements of nitrogen for the maximum production of a crop like wheat in calcareous soils.

The cropping results of the previous set of pot experiments showed that the application of 80 lb. of nitrogen per acre as cake met the nitrogen requirements of these soils for wheat

In order, therefore, to test these conclusions arrived at from pot experiments, field experiments were conducted in the Punjab Experimental Area of the Pusa Farm in the winter of 1934 in two ½ adjacent acre plots. Each of these plots was sub-divided into 18 equal sub-

plots of $\frac{1}{73}$ acre each measuring about 30 ft. north to south and 20 ft. east to west. A basal dressing of potash and phosphoric acid at the rate of 80 and 100 lb. per acre as potassium chloride and superphosphate respectively was given to all the sub-plots, and nitrogen as ammonium sulphate to the plots concerned. There were six treatments of six replications each.

The treatments were N_0, N_1, N_2, N_3, N_4 and N_5 representing respectively control with potash and phosphoric acid only but no nitrogen, and 40, 60, 70, 80 and 100 lb. of nitrogen per acre besides the basal dressings of potash and phosphoric acid as in the control plots.

Wheat seeds were sown on 30 October 1924 by means of a drill in 31 lines north to south, 9 in. apart, in each sub-plot. Rejecting one row of plants from all sides of each sub-plot in order to eliminate the border-effect, the wheat crop was harvested on 24 March 1935. In the interval, however, on 25 January 1935, five plants of each sub-plot were collected and 30 such plants from six sub-plots of each treatment photographed, after which their fresh weight was recorded, as given in Table IV.

TABLE IV

Fresh weight of wheat plants about 12 weeks old grown under increasing doses of ammonium sulphate in Pusa calcareous soil

Treatment per acre of soil	Weight of 30 wheat plants in gm.	Percentage of increase over control
N_0=Control, P and K only ...	380	—
N_1= 40 lb. of nitrogen ...	690	81.6
N_2= 60 ,, ,, ...	780	105.3
N_3= 70 ,, ,, ...	820	115.8
N_4= 80 ,, ,, ...	890	134.2
N_5=100 ,, ,, ...	1270	234.2

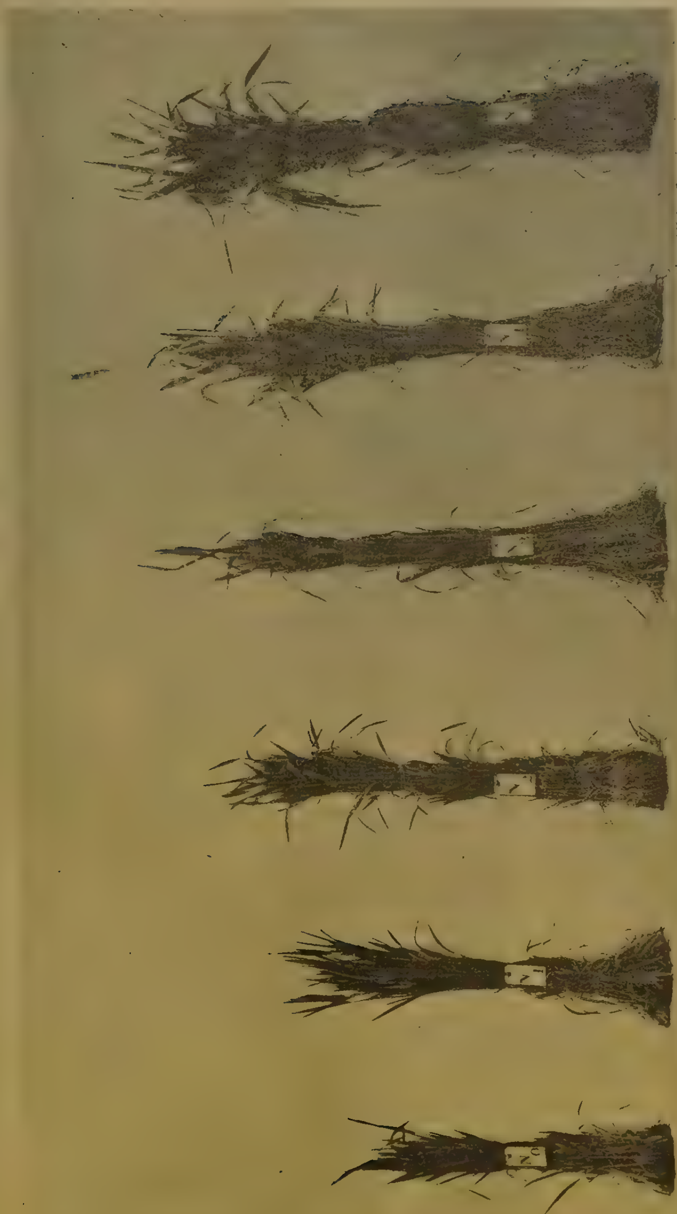
It is seen that the vegetative growth of wheat plants increases generally with increasing doses of nitrogenous manure. This can be visualized in Plate XXI, where the photograph of the corresponding wheat plants is given.

The mean yields of wheat grain with their statistical examination by Fisher's [1932] analysis of variance are set out in Table V.

TABLE V

Mean yields of wheat grain in field experiments with Pusa calcareous soil under increasing doses of ammonium sulphate

Treatment per acre of soil	Wheat 1934-35	
	Mean yield in lb.	Percentage of increase over control
N_0= Control, P and K only ...	13.25	—
N_1= 40 lb. of nitrogen ...	19.10	44.1
N_2= 60 ,, ,, ...	19.55	47.6
N_3= 70 ,, ,, ...	19.85	49.8
N_4= 80 ,, ,, ...	20.52	54.8
N_5=100 ,, ,, ...	21.20	60.0
Standard error for comparison of mean yields ...		1.68
Critical difference for 1 per cent ...		4.78
,, ,, ,, 5 per cent ...		3.50



Wheat plants growing under increasing doses of ammonium sulphate in Pusa calcareous soils

It is seen that the increase in the yield of wheat grain over the control varies between 44 and 60 per cent with increasing doses of ammonium sulphate and that the differences in mean yields of grain between the control and every other treatment are highly significant, being greater than the critical value of difference even for 1 per cent level of significance. Thus, of all the treatments, the application of 40 lb. of nitrogen per acre as ammonium sulphate meets the optimum requirements of nitrogen of these calcareous soils for the maximum production of a crop like wheat. The higher doses produce, no doubt, slightly better yields, which are not however significant. The cropping of the two sets of pot experiments showed that the application of 50 to 60 lb. of nitrogen per acre met the optimum requirements of nitrogen for these soils.

The economics of the manurial treatment shows that in *pot experiments* (1) 9 md. of apricot seed cake costing Rs. 13.8 per acre gave an extra yield of 15.2 md. of wheat over the control, (2) 11.5 md. of cake costing Rs. 17-4 per acre an extra yield of 8.3 md. of *ragi* as the residual effect, (3) 3.5 md. of ammonium sulphate costing Rs. 20-4 per acre an extra yield of 28.7 md. of wheat, and (4) in *field experiments*, 2.3 md. of ammonium sulphate costing about Rs. 13 per acre gave an extra yield of 5 md. of wheat over the control. Except the residual effect of the cake with *ragi*, all the other nitrogenous treatments gave economically significant yields which would justify the manurial treatment leaving a decent margin of profit to the cultivator.

Next it was considered worthwhile to see how the wheat grown under increasing doses of a nitrogenous fertilizer with basal dressings of potassic and phosphatic fertilizers absorbed important food materials. For this purpose, the representative samples of wheat grain collected from the six replicated sub-plots of each treatment were submitted to chemical analysis. The results obtained are given in Table VI.

TABLE VI

The chemical composition of wheat grain grown in field experiments with Pusa calcareous soil under increasing doses of ammonium sulphate

Nitrogen per acre of soil in lb.	Per cent constituents calculated on dry wheat grain					Mean yield of wheat grain in lb. per plot
	Ash	Sand	P_2O_5	K_2O	N	
N_0=Control ...	2.02	0.11	0.770	0.446	2.160	13.25
N_1= 40 ...	1.98	0.14	0.716	0.407	2.321	19.10
N_2= 60 ...	1 90	0.12	0.692	0.421	2.415	19.55
N_3= 70 ...	2.34	0.10	0.616	0.419	2.500	19.85
N_4= 80 ...	2.24	0.08	0.656	0.429	2.503	20.52
N_5=100 ...	2.22	0.15	0.626	0.397	2.547	21.20

It is seen that the nitrogen content of the wheat grain shows a marked increase with the increasing doses of nitrogenous fertilizer applied and the reverse is the case with P_2O_5 content. This result has an important bearing in showing the dangers of nitrogen fertilization from the point of view of plant nutrition. Potash content does not however exhibit any appreciable variation. It was found while growing *ragi* in field experiments detailed in Part I that its P_2O_5 content increased with the increasing doses of a phosphatic fertilizer and the reverse was the case with regard to its nitrogen content.

SUMMARY

1. Two series of pot experiments were started in Pusa calcareous soil with basal dressings of potash and phosphoric acid. In one of them increasing doses of

nitrogen was supplied as oil cake and in the other as ammonium sulphate. In the former series two crops were raised, viz. wheat and *ragi* (*Eleusine coracana*), the latter crop showing the residual effect of the manures. The cropping results showed that the application of 80 lb. of nitrogen per acre as cake met the optimum requirements of nitrogen of these calcareous soils for wheat, and that the residual effect of only 100 lb. of nitrogen per acre persisted till the succeeding crop of *ragi*.

In the latter series only a crop of wheat was raised which showed that the application of 60 lb. of nitrogen per acre as ammonium sulphate met the optimum requirements of nitrogen of these calcareous soils.

2. A similar series of field experiments with ammonium sulphate in Pusa calcareous soils showed that the application of 40 lb. of nitrogen per acre gave the maximum yield of wheat and thus met the optimum requirements of nitrogen for wheat in these soils.

3. All the cropping results for maximum production in both pot and field experiments were statistically and economically tested and found to be highly significant.

4. An examination of the mechanism of absorption of important food materials by the growing crop of wheat from the soil and the applied fertilizers indicated that the nitrogen content of the wheat grain showed a marked increase with the increasing doses of the nitrogenous fertilizer and the reverse was the case with P_2O_5 content. The result has an important bearing in showing the dangers of nitrogen fertilization from the point of view of plant nutrition. The potash content however did not exhibit any appreciable variation.

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COMPARATIVE STUDIES ON INDIAN SOILS

III. BASE EXCHANGE PROPERTIES

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Part I of the series dealt with the basis of the proposed climatic and colour divisions of Indian soils and Part II with the chemical composition of the soils and its variation in the individual profiles due to different climatic conditions under which the soils had been formed. The present paper deals with the base exchange properties of the soils including measurements of the total exchange capacity, individual exchangeable bases, and *p*H. These important soil properties vary in the different climatic zones and also in a given profile. It is proposed to study these variations in the light of the composition of the clay and on the basis of the climatic effects. The soils were classified on climatic and colour bases as follows :

Arid	...	From Mirpurkhas, Mianwali, Lyallpur, Haripur-Hazara.
Semi-Arid	...	From Lahore, Gurdaspur, Tabiji, Makrera, Kharua, Indore, Akola, Padegaon, Coimbatore, Koilpatti, Nandayal, Hagari, Anakapalle, Surat, Delhi.
Humid	...	From Shahjahanpur, Ranchi, Nagpur, Powarkhera, Labhandi, Chandkhuri, Waraseoni, Kheri-Adhartal, Samalkot, Berhampur, Chinsura.

Per-humid	...	From Kangra, Dacca, Rangpur, Jorhat, Karimganj, Sylhet, Sirsi, Taliparamba.
Calcareous	...	From Peshawar, Sakrand, Karachi, Padrauna, Pusa.
Black	...	From Hagari, Nandayal, Koilpatti, Padegaon, Kharua, Indore, Akola, Nagpur, Powarkhera, Labhandi, Kheri-Adhartal.
Brown	...	From Anakapalle, Samalkot, Surat, Tabiji, Kangra, Chinsura, Rangpur, Sylhet, Delhi.
Red	...	From Coimbatore, Taliparamba, Sirsi, Chandkhuri, Waraseoni, Ranchi, Dacca, Jorhat.
Pink & grey	...	From Berhampur, Makrera, Mirpurkhas, Haripur-Hazara, Mianwali, Lyallpur, Lahore, Gurdaspur, Shahjahanpur, Karimganj.

As the field observations did not always help in demarcating the horizons of the profile, one foot soil samples from each profile were conveniently collected down to a depth of 5 ft. This collection was made in the months of February and March of 1937. Altogether 43 such soil profiles were examined from uncultivated lands. As far as possible the soil profiles collected represented different areas. The soil properties studied refer to individual soil samples only.

Experimental

The following methods of determination were found satisfactory and finally adopted after giving trials to several of the more common methods in vogue.

Total exchange capacity. By Schollenberger and Dreibelbis' [1930] neutral N-ammonium acetate method ; the amount of NH_4 adsorbed was estimated.

Exchangeable bases. Na, K and Mg in the ammonium acetate leachate obtained by Schollenberger's method, and Ca according to Hissink's [1923] method.

Na was calculated by subtracting the amount of K from the sum of Na+K. Exchangeable H was not directly estimated. Account was taken of the soluble cations.

*p*H was determined by the Biilmann's [1927] quinhydrone electrode using as reference Veibel's solution which is a KCl-HCl mixture having a constant *p*H 2.03. For alkaline soils, the *p*H was determined by means of the antimony electrode using the modification and formula given by Puri [1932].

Discussion

The results are given in tabular form in the appendix.

Thirty-three out of forty-three soils examined contain free $CaCO_3$, the amount of which varies greatly. The highly calcareous soils occur mostly in the arid and semi-arid regions, excepting those from Pusa, which fall in the humid region. It is natural that in the humid and per-humid regions the high precipitation will tend to dissolve the bases ; in fact, the acid soils occur in these regions. The calcareous soils have generally a high base exchange capacity and a higher SiO_2/Al_2O_3 ratio than those of the acid soils. The *p*H values are high and above 7.0. In some of the samples, where the $CaCO_3$ content is small, the reaction is just below 7.0.

Profiles from Kangra, Shahjahanpur, Jorhat, Karimganj, Sylhet, Dacca, Rangpur, Chinsura, Sirsi, and Taliparamba contain no $CaCO_3$ and the *p*H is on the acidic side ranging from 4.03 to to 6 93, excepting profiles from Shahjahanpur and Chinsura in which the reaction of the soils is alkaline. In the case of profile from Ranchi the first three layers are acidic and contain no $CaCO_3$, but the lower two layers are slightly alkaline and contain very small amounts of $CaCO_3$. The soils from these profiles excepting those from Chinsura have low b.e.c. (base exchange capacity) and the SiO_2/Al_2O_3 ratios vary from 1.80 to 2.74.

From the data it is possible to distinguish three groups of profiles : (1) those in which the b.e.c. of the soil gradually increases downwards — these include the profiles from Gurdaspur, Mirpurkhas, Nagpur, Jorhat, Dacca, Surat, Nandayal,

Berhampur, and Delhi, (2) those in which the b.e.c. of the soil gradually decreases downwards—these include the profiles from Kangra, Karachi, Padrauna, Kheri-Adhaital, Powarkhera, Rangpur, Sirsi, Padegaon, Coimbatore, Taliparambe, Hagari, Samalkot, and Anakapalle; and (3) those in which the b.e.c. of the soil has a maximum value in some intermediate depths which are usually confined to the third and the fourth layers—these include profiles from Haripur-Hazara, Lahore, Shahjahanpur, Ranchi, Akola, Waraseoni, Labhandi, Chandkhuri, Indore, Kharua, Makrera, Tabiji, Karimganj, Sylhet, Koilpatti and Pusa. There are a few profiles from Peshawar, Lyallpur, Mianwali, and Chinsura in which the b.e.c. remains almost constant. The profile from Sakrand shows a minimum b.e.c. of the soil at the second and the third foot.

The variations in the content of clay (given in the appendix) which generally makes the highest contribution towards the b.e.c. are almost similar to the b.e.c. in the three groups with, however, some exceptions. They are discussed later. Clay is the product of weathering or decomposition of rocks and is likely to vary in different profiles due to climatic variations or the parent rock. This variation is reflected in the magnitude of the b.e.c. of the clay. Thus a montmorillonitic clay will have a higher b.e.c. than a kaolinitic clay. The b.e.c. of the soil also will vary for the same reason, and in a given profile the variations may be due both to the nature and the content of the clay. As the clay contents in most cases vary in a manner similar to the b.e.c., it is likely that either eluviation or illuviation of the clay has taken place.

Of the exchangeable bases, Ca is the major constituent. The variation of this exchangeable cation in the profile is similar to the b.e.c. Mg comes next in amount and its percentage is particularly high in the black types of soils. Mg is a constituent of the lattice of many clay minerals and its predominance is an indication that the soils contain magnesian minerals. Whatever may be the relative distribution of Ca in the entire profile, Mg generally shows an increase downwards. The removal of Mg from the complex by leaching is perhaps less active downwards. It is also to be noted that the Mg-bearing minerals are mostly located in the semi-arid regions where the chances of the removal of Mg would naturally be small. Exchangeable K hardly exceeds 1 m.e. and becomes a major constituent in only two soils from Berhampore (Madras) and Chandkhuri (Central Provinces). Exchangeable Na, as already pointed out, has been determined by difference. It will naturally include accumulated errors of several measurements. But as it would appear from the data, exchangeable Na is high in some of the saline soils of the arid and semi-arid regions and in the black and black cotton soils. Some of the latter types of soil contain sodium salts, but the experimental error will obviously be high in the case of these soils having high b.e.c. and other exchangeable bases.

Columns 10 and 11 of the table in the appendix give respectively the values of the b.e.c. calculated per 100 gm. of clay and the SiO_2/Al_2O_3 ratios of the clay fractions. In calculating the values of the b.e.c., it has been assumed that it is contributed solely by the clay fraction. The organic matter content being generally small, the assumption may be partly justified, but these values are likely to be misleading particularly in cases where the percentage of clay is small, so that the contribution of even a small amount of organic matter and also of silt might be appreciable. Instances of such cases are the soils from Sakrand, Karachi, Padrauna, Jorhat, Tabiji, Rangpur and Pusa. The very high values of the calculated b.e.c. of the clays in the profiles from Sakrand, Karachi, Tabiji and Rangpur may be due to this.

According to the variation of the b.e.c. per 100 gm. of clay the profiles may be grouped under three heads : (i) (a) the b.e.c. of the clay gradually decreases downwards attaining in some cases a more or less constant value, (b) the b.e.c. decreases sometimes abruptly to very low values ; (ii) the b.e.c. increases downwards ; and (iii) the b.e.c. remains almost unchanged.

To group (i) (a) belong the profiles from Haripur-Hazara, Gurdaspur, Kangra, Lyallpur, Mirpurkhas, Shahjahanpur, Tabiji, Dacca, Chinsura, Coimbatore, Hagari, and Delhi. The alteration in the b.e.c. is not generally associated with a change in the com-

position of the clay fraction as judged from the ratio of SiO_2/Al_2O_3. The higher b.e.c. of the top soils and its gradual decrease downwards are perhaps due to the presence of organic matter, the content of which generally decreases downwards.

Profiles from Sylhet, Sirsi, Taliparamba, Koilpatti, Samalkot, and Anakapalle belong to group (i) (b). Of these, the soils from the first three are highly acidic, those from the other three are alkaline. The influence of organic matter alone does not explain the large decrease. In the first three probably a decomposition of the complex takes place, although there is nothing in the SiO_2/Al_2O_3 ratios to indicate the existence of such processes. The low values of the b e.c. particularly in the samples from lower horizons of profiles from Sylhet, Sirsi, Taliparamba and Anakapalle suggest kaolinisation. A similar process is probably responsible for the low b.e.c. of the clay in the profiles from Ranchi, Waraseoni and Chandhkuri. The profiles from Koilpatti, Samalkot and Anakapalle, especially the last two which show alkaline reaction, contain only small amounts of $CaCO_3$, showing that the 'reserve' base status is low, possibly as a result of the solvent action of the percolating solutions.

To group (ii) belong the profiles from Nagpur, Kheri-Adhartal, Indore, Makrera and Karimganj. From the available data it is not easy to find a reasonable explanation of the observed increase at lower depth. However, an alteration in the mineralogical make-up of the complex in the different horizons of the profiles may be responsible for the observed variations.

In profiles from Peshawar, Lahore, Mianwali, Ranchi, Akola, Waraseoni, Labhandi, Chandkhuri, Kharua, Padegaon, Surat, Nandayal, and Berhampur which belong to group (iii) the b.e.c. remains almost constant, showing evidently that the composition of the clay has not materially changed and the influence of organic matter is almost uniform throughout the profile.

The exchange properties of the soils from the different places and their variations down the profile have been discussed above in relation to the chemical and other properties of the clay complex. It is interesting to see how the base exchange properties of the soils vary in the different climatic zones and according to the colour of the soil. In this comparative study the average values of the different determinations have been conveniently used. Sometimes the values within a particular zone or of a soil of a given colour show wide divergences, and it may not be justified in such cases to calculate the average values.

TABLE I

Total base exchange capacity in m. e. per 100 gm. of soil or clay (on climatic basis)

Depth	Arid		Semi-arid		Humid		Per-humid		Calcareous	
	Soil	Clay	Soil	Clay	Soil	Clay	Soil	Clay	Soil	Clay
1st ft.	9.3	61.2	34.0	91.7	26.9	71.2	9.5	61.2	9.5	109.6
2nd "	10.7	59.1	37.5	92.8	25.6	57.3	10.0	41.7	7.8	102.8
3rd "	10.9	53.1	35.5	81.1	26.7	59.3	10.6	39.4	6.6	84.4
4th "	11.4	45.9	34.1	80.1	27.8	65.1	9.9	33.0	6.8	92.8
5th "	10.9	45.4	32.4	81.7	26.5	60.7	9.3	38.6	8.1	114.7

TABLE II

Total base exchange capacity in m. e. per 100 gm. of soil or clay (on colour basis)

Depth	Black		Brown		Red		Pink and grey	
	Soil	Clay	Soil	Clay	Soil	Clay	Soil	Clay
1st ft.	45.2	77.5	20.2	102.8	11.9	45.6	8.6	57.0
2nd „	45.8	76.0	17.4	69.2	13.7	40.0	10.9	56.9
3rd „	45.6	73.3	18.1	64.5	12.3	34.6	12.0	53.8
4th „	41.9	70.8	20.4	64.1	12.2	36.0	11.8	50.6
5th „	38.3	65.6	19.0	67.2	107	38.8	1.1	49.6

Tables I and II give respectively the average values of the b.e.c. of the soil and the clay isolated from it in the different climatic zones and their variations according to the colour of the soil. The values for both the soil and the clay decrease in the various zones in the order: semi-arid> humid> arid> per-humid; and according to colour the same values decrease in the order: brown> black> pink and grey> red. The average b.e.c.'s of the soils down the profile do not show much variation, although, while considering the individual profiles, appreciable variations were noticed. There is, however, a general tendency of the b. e. c. of the clays to decrease, as also observed previously.

TABLE III

Soil reaction, exchangeable bases and base exchange capacity of soils

Soil group	Per-humid	Humid	Semi-arid	Arid	Red	Pink and grey	Brown	Black	Calcareous
*p*H	5.21	6.84	7.72	7.35	5.66	7.20	6.72	7.67	7.54
Exchange capacity	9.5	26.9	34.0	9.3	11.9	8.6	20.2	48.5	9.5
Exchangeable calcium	3.17	18.67	25.79	5.96	5.73	5.63	13.93	38.40	6.10
Total exchangeable bases	5.48	25.36	34.72	9.55	9.75	8.57	19.10	48.20	7.36

Table III gives the average values of the *p*H, exchangeable Ca, total exchangeable bases and the b.e.c. of the surface soils tabulated on both climatic and colour bases. A regular variation is not observed, but, in general, the soils from semi-arid and arid zones and those having black and pink or grey colour have alkaline reaction, whereas those from humid and per-humid zones and those having red and brown colours are acidic, the acidity being pronounced in the case of per-humid and red soils. Exchangeable Ca is, according to expectation, relatively large in the soils having high *p*H and small in those of low *p*H. A similar variation is observed in the case of the total exchangeable bases, the soils of arid and semi-arid regions and those having black and pink or grey colour and a high *p*H being completely base-saturated.

TABLE IV

Percentage exchangeable bases in terms of the base exchange capacity

Exchangeable base	Arid	Semi-arid	Humid	Per-humid	Calcareous	Black	Brown	Red	Pink and grey
Ca	64.5	67.2	72.6	28.0	69.4	81.6	66.5	44.7	65.2
Mg	16.1	19.7	18.6	12.8	10.8	23.3	16.3	13.5	14.3
Na	19.6	9.2	5.0	5.6	6.3	9.4	4.1	10.9	13.0
K	4.8	1.5	3.4	3.1	4.3	1.6	2.4	4.7	5.3

The relative percentages of the exchangeable bases in the soils of the different climatic zones and those having different colours are shown in Table IV. Exchangeable Ca constitutes the largest proportion in all the zones excepting those from the per-humid region and the red soils. Exchangeable Mg is low in the soils of the per-humid zone and the red soils compared with those of the remaining zones excepting, however, the calcareous soils, where exchangeable Mg has the lowest value. Exchangeable K varies from 1.5 to 5.3 per cent and exchangeable Na which has been calculated by difference is relatively high especially in the arid soils and in red and pink or grey soils.

SUMMARY

Soil profiles, 43 in number, collected from all over India have been examined with regard to the *p*H and the contents of the exchangeable bases, base exchange capacity of the soil samples and the variation of these properties with depth. According to the variation of the base exchange capacity of the soil and of the clay, three groups of soil profiles have been distinguished. The variations in these three groups have been discussed in the light of the possible nature of the clay mineral and its content. Exchangeable Ca constitutes the major element, then comes Mg, followed by Na and K in order. Mg is particularly high in black and black cotton types of soils and Na in saline soils. Thirty-three out of forty-three soil profiles contain $CaCO_3$ and these soils have alkaline reaction. The rest are acidic. The calcareous soils have generally a high base exchange capacity, whereas the acidic soils possess a low b.e.c.

The soil profiles which naturally fall in different climatic and colour divisions are also distinguished by their base exchange properties.

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Appendix

Exchangeable bases, pH, etc. of soils

Depth in ft.	Clay percentage	$CaCO_3$ percentage	*p*H	M. E. Exchangeable bases per 100 gm. of soil: Ca	Mg	K	Na	Total ex. cap.	B. E. C. per 100 gm. clay	SiO_2 / Al_2O_3
Arid										
				Mirpurkhas—Sind						
0—1	16.24	9.86	7.34	6.25	3.09	0.27	1.70	8.17	50	2.73
1—2	18.43	9.43	7.48	5.50	3.25	0.39	1.24	8.14	44	2.64
2—3	27.32	8.25	7.63	8.30	4.45	0.24	1.30	11.64	42	2.71
3—4	38.68	6.35	7.64	9.67	5.17	0.38	2.00	13.79	35	2.58
4—5	40.10	5.77	7.81	9.20	5.36	0.14	1.83	14.07	35	2.62
				Mianwali—Punjab						
0—1	13.58	6.36	7.31	3.10	0.87	0.78	0.47	5.56	41	3.18
1—2	12.94	4.80	7.51	5.30	0.76	1.00	2.00	7.43	57	3.16
2—3	12.13	6.48	7.67	4.72	0.58	1.05	0.85	6.43	53	3.30
3—4	11.71	10.55	7.91	3.95	0.47	0.65	1.44	4.86	41	3.5[illegible]
4—5	7.24	0.55	7.94	2.40	0.62	0.67	1.48	5.30	73	2.81
				Lyallpur—Punjab						
0—1	9.89	0.66	7.59	5.55	0.16	0.32	0.50	7.10	72	3.09
1—2	12.40	1.15	7.10	6.60	0.14	0.59	0.96	8.40	64	3.36
2—3	11.92	0.30	6.56	5.05	0.15	0.59	1.30	7.60	63	3.18
3—4	13.84	0.90	6.46	5.95	0.16	0.52	0.70	8.55	61	3.20
4—5	12.59	0.29	6.35	5.40	0.17	0.55	1.10	7.50	59	3.86
				Haripur-Hazara—Punjab						
0—1	21.10	8.68	7.14	8.95	1.73	0.22	4.26	15.37	73	2.78
1—2	28.80	5.06	7.16	9.40	3.05	0.19	2.53	18.90	65	2.95
2—3	30.48	4.77	7.04	12.50	1.18	0.22	4.06	17.80	56	2.91
3—4	35.21	2.63	7.03	8.72	1.03	0.67	7.91	18.40	52	3.02
4—5	36.10	3.70	7.15	10.60	1.88	0.66	4.30	16.70	46	2.94
Semi-arid										
				Lahore—Punjab						
0—1	17.66	1.92	8.21	7.70	0.20	0.50	0.80	9.90	56	2.92
1—2	21.80	1.44	7.66	8.55	0.34	0.45	0.53	12.30	56	2.92
2—3	26.86	1.12	7.52	9.25	0.18	0.71	—	14.50	53	2.60
3—4	24.30	1.92	8.07	8.70	0.17	0.44	—	12.55	51	2.75
4—5	19.14	4.71	8.12	9.20	0.06	0.43	—	9.95	52	2.60
				Gurdaspur—Punjab						
0—1	11.58	1.23	7.88	5.45	0.03	0.34	0.76	7.05	60	2.45
1—2	20.65	0.38	7.38	8.10	0.25	0.35	1.11	9.90	47	2.45
2—3	23.88	0.17	7.11	9.15	0.38	0.32	1.40	11.50	48	2.38
3—4	24.01	0.35	7.05	8.20	0.63	0.19	1.18	10.90	45	2.45
4—5	24.74	0.13	7.13	7.45	0.53	0.23	1.28	10.75	43	2.44
				Akola—C. P.						
0—1	57.74	10.00	7.91	36.95	11.02	0.92	3.10	49.70	86	3.73
1—2	60.48	7.66	8.39	36.54	13.61	1.03	1.61	50.03	82	3.47
2—3	62.44	8.40	8.47	33.29	13.29	0.91	5.70	53.70	86	3.68
3—4	64.14	8.80	8.57	30.40	13.84	0.90	5.81	52.60	82	3.51
4—5	64.38	11.70	8.57	25.39	13.40	0.98	6.89	52.00	80	3.89

Appendix

Exchangeable bases, pH, etc. of soils—cont.

Depth in ft.	Clay percentage	$CaCO_3$ percentage	*p*H	M. E. Exchangeable bases per 100 gm. of soil: Ca	Mg	K	Na	Total ex. cap.	B.E.C. per 100 gm. clay	SiO_2 / Al_2O
Semi-arid				*Indore—C. I.*						
0—1	65.40	4.70	7.78	44.60	7.09	0.75	1.31	48.57	74	3.16
1—2	66.00	2.50	7.81	42.80	7.19	0.80	2.07	50.71	76	3.97
2—3	64.50	0.93	7.53	39.02	9.29	0.39	2.27	53.14	82	3.43
3—4	61.30	1.30	7.41	37.96	9.95	0.91	2.90	52.00	84	3.22
4—5	47.30	2.57	7.67	38.26	12.43	0.50	1.04	49.71	105	3.32
				Kharua—C. I.						
0—1	52.70	2.98	7.51	41.19	1.90	0.78	1.26	45.00	85	3.63
1—2	52.78	6.00	7.45	44.36	1.92	0.64	2.04	50.71	96	3.65
2—3	54.84	6.64	7.38	42.75	2.27	0.78	2.41	49.00	89	3.56
3—4	53.11	6.16	7.60	43.04	2.37	0.67	2.05	49.50	93	3.57
4—5	44.32	5.68	7.63	34.16	2.06	0.55	2.29	40.50	90	3.39
				Makrera—Ajmer-Merwara						
0—1	8.36	1.85	6.65	4.60	1.55	0.62	2.20	9.79	117	3.00
1—2	13.67	0.21	6.75	6.51	2.04	0.57	0.42	10.86	79	2.96
2—3	15.51	0.16	6.80	11.05	2.66	0.54	1.51	13.14	84	3.07
3—4	14.79	17.70	6.98	10.94	2.84	0.29	—	13.36	90	2.77
4—5	8.16	14.66	7.00	8.14	2.59	0.85	3.24	10.71	131	2.89
				Tabiji—Ajmer-Merwara						
0—1	5.04	1.03	7.15	3.00	1.10	—	1.96	6.28	124	2.81
1—2	6.05	2.22	6.85	3.75	0.84	0.49	1.72	6.36	105	2.49
2—3	6.86	1.64	7.57	2.30	1.74	0.29	1.22	6.78	98	2.70
3—4	9.30	2.90	7.86	2.45	2.54	0.36	1.38	7.11	76	2.93
4—5	3.21	1.13	8.43	0.25	2.89	0.55	0.41	3.16	98	2.92
				Padegaon—Bombay						
0—1	74.75	9.80	7.97	48.00	15.22	1.16	5.42	67.14	89	4.37
1—2	76.13	7.00	8.19	44.56	15.14	1.17	4.51	68.00	89	4.29
2—3	76.92	8.20	8.03	41.59	15.43	1.53	8.37	66.86	86	4.65
3—4	70.00	7.70	7.98	40.30	15.68	0.96	6.74	59.21	84	4.80
4—5	74.29	9.80	7.55	30.41	12.95	0.35	12.14	60.00	80	4.45
				Surat—Bombay						
0—1	47.10	1.25	7.17	40.82	8.27	0.53	1.76	48.56	103	3.13
1—2	43.00	0.41	7.21	41.82	7.45	0.45	2.07	53.64	121	3.69
2—3	43.10	0.57	7.22	43.52	9.13	0.50	0.53	53.07	123	3.65
3—3½	40.30	0.62	7.14	41.52	9.53	0.62	0.49	53.70	133	3.45
3½—4½	43.00	0.57	7.09	42.71	9.93	0.46	0.65	54.14	126	3.88
				Coimbatore—Madras						
0—1	31.67	1.05	7.05	21.4	6.0	0.61	3.8	32.3	102	2.10
1—2	37.26	0.97	6.80	17.1	6.7	0.57	6.4	34.4	92	3.01
2—3½	38.74	19.00	7.18	17.3	3.9	0.35	5.4	27.0	69	2.86
3½—5	26.95	19.40	7.03	10.7	4.7	0.22	5.5	21.1	78	3.33
				Koilpatti—Madras						
0—1	62.90	2.48	8.05	44.0	14.6	0.64	0.4	57.4	91	3.83
1—2	64.98	1.92	8.11	43.9	12.8	0.59	5.0	60.8	92	3.88
2—3	72.52	3.73	7.30	46.7	10.6	0.48	2.0	59.8	82	3.87
3—4	71.14	4.13	7.14	35.7	13.5	0.37	3.6	53.2	74	4.05
4—5	71.69	3.87	7.15	13.5	17.3	0.14	6.0	36.9	51	4.24

APPENDIX

Exchangeable bases, pH, etc. of soils—cont.

Depth in ft.	Clay percentage	$CaCO_3$ percentage	pH	M. E. Exchangeable bases per 100 gm. of soil: Ca	Mg	K	Na	Total ex. cap.	B.E.C. per 100 gm. clay	$\frac{SiO_2}{Al_2O_3}$
Semi-arid				*Hagari—Madras*						
0—1	43.95	7.10	8.75	37.6	8.9	0.33	2.9	51.5	117	3.83
1—2	52.79	9.30	8 60	36.2	9.6	0.27	4.5	51.2	97	3.16
2—3	59.06	7.76	8.01	32.1	9.6	0.25	7.1	49.7	84	3.28
3—4	54.89	5.43	7.95	28.3	10.9	0.23	6.5	48.5	88	3.47
4—5	52.21	0.70	8.49	25.5	11.8	0.29	8.2	47.9	91	3.17
				Nandayal—Madras						
0—1	57.29	3.94	8.47	31.6	10.9	0.46	6.1	50.0	87	3.37
1—2	61.45	2.80	8.58	28.5	12.7	0.40	9.4	51.1	83	3.17
2—3	64.55	3.40	8.71	25.4	15.9	0.31	11.5	55.1	85	3.19
3—4	65.94	4.47	9.16	22.4	18.3	0.29	13.6	56.1	85	3.38
4—5	66.40	4.78	9.15	20.1	20.3	0.26	16.7	58.3	87	3.04
				Anakapalle—Madras						
0—1	9.48	0.09	7.91	12.4	4.4	0.38	0.5	17.1	180	3.18
1—2	17.06	0.28	7.63	7.6	2.9	0.60	0.3	10.3	60	3.15
2—3	24.10	0.18	7.89	2.4	1.1	0.27	0.4	4.2	17	3.09
3—4	27.71	0.08	8.17	3.1	1.4	0.28	0.3	4.3	15	3.29
4—5	26.28	0.15	7.93	2.1	1.0	0.05	0.1	2.9	11	3.31
				Delhi						
0—1	10.33	1.03	7.30	7.60	2.13	0.34	0.02	9.30	90	3.84
1—2	18.45	0.27	7.01	8.65	1.38	0.32	0.19	12.70	68	3.36
2—3	24.04	0.13	6.98	10.65	1.80	0.44	0.68	15.55	64	3.30
3—4	24.27	0.42	7.16	13.40	2.58	0.35	0.25	16.60	68	3.63
4—5	22.86	0.71	7.41	12.20	2.26	0.40	0.28	16.90	73	3.64
Humid				*Shahjahanpur—U. P.*						
0—1	18.58	—	8.00	4.25	0.03	0.15	0.76	7.80	42	2.74
1—2	20.40	—	7.68	7.30	0.27	0.24	0.90	12.20	59	2.21
2—3	24.70	—	7.33	7.26	0.43	0.32	1.00	12.55	50	2.11
3—4	25.14	—	7.27	7.41	0.13	0.36	1.31	11.85	47	2.09
4—5	21.06	—	7.21	6.40	0.22	0.29	0.91	8.85	42	2.12
				Ranchi—Bihar						
0—1	42.22	—	6.57	5.75	0.24	0.53	2.09	10.00	23	2.22
1—2	41.31	—	6.50	7.10	0.30	0.24	0.90	13.00	31	2.04
2—3	42.47	—	6.81	8.18	0.27	0.22	1.42	13.60	32	2.11
3—4	35.72	0.10	7.14	8.70	0.13	0.17	1.04	12.80	35	2.09
4—5	40.17	0.16	7.43	7.98	0.15	0.37	1.57	10.80	26	2.20
				Nagpur—C. P.						
0—1	59.55	2.73	7.31	44.15	11.89	0.93	0.44	57.14	95	3.17
1—2	63.11	0.74	7.51	43.50	8.42	0.93	1.36	54.21	86	3.51
2—3	66.32	0.74	7.38	41.30	16.79	1.61	2.94	59.43	89	3.43
3—4	65.71	0.61	7.54	36.15	19.19	0.91	5.09	60.00	91	3.54
4—5	64.46	5.45	8.04	39.60	22.29	0.84	2.84	64.40	100	3.53
				Waraseoni—C. P.						
0—1	21.67	0.23	6.46	5.44	1.26	0.49	—	8.57	39	2.49
1—2	40.35	0.07	6.95	9.14	1.46	0.31	1.11	12.42	30	2.36
2—3	40.83	0.25	7.95	10.32	2.01	0.18	2.09	14.50	35	2.36
3—4	34.40	0.39	7.56	6.59	1.51	0.26	1.03	10.00	29	2.31
4—5	22.18	0.24	7.09	3.84	1.46	0.20	0.50	6.57	29	2.27

APPENDIX

Exchangeable bases, pH, etc. of soils—cont.

Depth in ft.	Clay percentage	$CaCO_3$ percentage	*p*H	M. E. Exchangeable bases per 100 gm. of soil: Ca	Mg	K	Na	Total ex. cap.	B.E.C. per 100 gm. clay	$\frac{SiO_2}{Al_2O_3}$
Humid				***Labhandi—C. P.***						
0—1	60.07	0.13	6.41	31.84	7.90	0.50	1.62	40.71	67	2.75
1—2	62.47	0.03	6.47	30.64	8.20	0.59	1.40	39.43	63	2.65
2—3	61.14	0.03	6.68	29.83	8.20	0.82	2.23	43.43	71	2.81
3—4	61.59	0.08	7 68	30.28	10.77	0.82	1.45	42.14	68	3.11
4—5	60.61	0.13	7.75	28.43	7.59	0.45	1.26	37.43	61	3.00
				Chandkhuri—C. P.						
0—5 in.	18.12	0.40	7.16	2.50	0.77	2.88	0.33	6.85	37	2.23
5—16 ,,	48.33	0.16	6.54	6.09	3.32	4.74	1.64	16.64	34	2.06
16—28 ,,	36.36	0.30	6.68	6.21	1.90	2.38	1.35	12.07	29	2.11
28—40 ,,	31.66	0.20	7.30	6.68	1.54	1.89	0.10	9.93	31	2.07
40—52 ,,	38.65	0.16	6.87	8.16	2.60	1.95	0.80	14.28	38	3.80
52—60 ,,	34.08	0.23	6.64	7.28	2.24	2.21	1.38	13.64	40	2.11
				Kheri-Adhartal—C. P.						
0—1	49.35	0.45	7.51	34.92	5.41	0.58	1.06	38.72	78	2.96
1—2	51.01	0.33	7.40	35.07	6.67	0.53	0.74	39.40	77	2.47
2—3	42.35	2.99	7.40	33.63	7.31	0.51	0.86	37.65	88	3.13
3—4	31.86	3.56	7.45	27.72	6.95	0.43	1.16	32.04	100	3.41
4—5	24.10	2.41	7.31	25.37	5.95	0.43	1.46	27.50	114	3.30
				Powarkhera—C. P.						
0—1	57.50	0.50	6.68	40.78	5.34	0.93	1.81	48.86	85	3.13
1—2	52.28	0.77	6.99	40.78	5.32	0.94	0.94	46.71	89	2.99
2—3	59.69	0.43	7.17	38.13	5.26	0.79	1.56	45.57	76	3.28
3—4	51.98	0.57	7.23	35.83	4.30	0.79	2.20	44.43	85	3.29
4—5	62.24	0.84	7.46	36.07	4.16	0.82	2.38	44.00	70	3.19
				Chinsura—Bengal						
0—1	50.61	—	6.39	23.80	8.11	1.20	1.11	35.64	70	2.84
1—2	53.72	—	7.31	25.35	5.51	1.02	2.01	34.80	64	2.75
2—3	55.85	—	7.70	24.85	6.07	1.38	2.06	33.93	60	2.91
3—4	58.47	—	7.79	24.15	6.04	0.67	3.09	36.21	61	3.14
4—5	62.47	—	7.74	28.80	5.11	1.07	1.15	35.57	56	2.96
				Samalkot—Madras						
0—1	24.88	0.50	7.06	23.1	9.2	0.45	0.4	32.8	131	3.40
1—2	36.62	0.59	8.52	7.1	2.8	0.15	—	9.2	25	3.34
2—3	36.18	0.51	8.78	8.7	3.4	0.23	—	11.5	31	3.16
				Berhampur—Madras						
0—1	12.84	0.06	6.05	2.92	0.92	0.33	0.85	4.29	33	3.99
1—2	21.79	—	6.12	5.02	1.74	1.00	0.28	8.00	36	3.14
2—3	29.86	0.10	6.93	6.62	2.38	2.20	0.56	12.00	40	3.24
3—4	30.45	0.07	7.08	8.67	2.20	2.78	0.92	14.30	46	3.05
4—5	41.21	0.17	7.13	11.42	3.00	3.23	1.62	16.30	39	3.05

APPENDIX

Exchangeable bases, p*H*, *etc. of soils*—cont.

Depth in ft.	Clay percentage	$CaCO_3$ percentage	*p*H	M. E. Exchangeable bases per 100 gm. of soil: Ca	Mg	K	Na	Total ex. cap.	B.E.C. per 100 gm. clay	SiO_2/Al_2O_3
Per-humid				*Kangra—Punjab*						
0—1	11.55	—	6.93	10.25	0.06	0.35	0.82	12.80	110	2.58
1—2	13.75	—	6.77	9.25	0.06	0.28	0.46	11.95	86	2.60
2—3	13.53	—	6.77	6.55	—	0.22	0.50	8.90	65	2.69
3—4	11.51	—	6.81	6.80	0.39	0.35	0.64	9.10	79	2.48
4—5	12.38	—	6.38	6.05	0.23	0.18	0.47	8.40	67	2.27
				Jorhat—Assam						
0—1	6.80	—	4.26	0.05	0.44	0.32	2.45	4.85	71	2.12
1—2	8.98	—	4.10	—	0.10	0.23	0.48	7.00	77	1.97
2—3	10.74	—	4.05	—	0.66	0.25	0.23	6.30	58	2.03
3—4	9.78	—	4.03	—	0.63	0.26	0.48	7.14	73	2.00
4—5	6.00	—	4.10	—	0.86	0.21	0.31	7.46	124	1.80
				Karimganj—Assam						
0—1	20.95	—	5.81	4.55	4.46	0.16	0.94	10.96	52	2.27
1—2	19.97	—	5.88	5.40	5.23	0.18	0.65	12.61	63	2.30
2—3	20.99	—	5.80	5.90	4.75	0.28	1.05	13.25	63	2.31
3—4	16.04	—	5.91	4.85	4.00	0.28	0.80	9.86	61	2.31
4—5	14.02	—	6.22	4.85	3.98	0.25	0.92	11.04	78	2.31
				Sylhet—Assam						
0—1	11.69	—	4.84	1.90	0.42	0.23	0.26	9.14	78	2.05
1—2	32.30	—	4.45	2.07	1.05	0.24	0.18	14.68	45	1.97
2—3	48.06	—	4.17	1.90	0.76	0.40	0.57	26.57	55	2.25
3—4	81.08	—	3.94	—	0.82	0.53	0.52	15.43	19	2.08
4—5	54.83	—	4.14	—	0.83	0.59	0.74	11.71	21	2.19
				Dacca—Bengal						
0—1	19.93	—	5.69	3.10	1.01	0.34	1.04	7.75	38	2.32
1—2	39.55	—	4.64	2.08	0.83	0.39	0.82	10.18	25	2.29
2—3	46.47	—	4.74	2.58	1.91	0.50	0.21	12.75	27	2.27
3—4	44.96	—	4.94	3.45	2.25	0.36	0.49	13.95	31	2.38
4—5	45.82	—	5.24	3.95	2.60	0.30	0.70	12.15	26	2.43
				Rangpur—Bengal						
0—1	6.41	—	5.69	2.52	0.85	0.65	1.03	10.43	162	1.37
1—2	5.08	—	5.83	0.48	0.08	0.70	0.55	2.71	53	1.97
2—3	0.59	—	5.96	—	0.42	0.36	0.16	2.21	374	3.04
3—4	1.83	—	5.97	Having 96 per cent coarse sands, soils were not examined						1.44
4—5	0.90	—	6.06	for exchangeable bases						1.39
				Sirsi—Bombay						
0—1	17.23	—	3.78	1.25	0.30	0.52	0.21	10.86	63	1.98
1—2	21.85	—	4.17	2.38	0.75	0.42	0.17	12.36	56	1.89
2—3	27.80	—	4.20	2.20	0.85	0.10	0.35	7.68	27	2.01
3—4	29.50	—	4.12	2.45	0.95	0.15	0.46	8.02	27	1.94
4—5	21.29	—	4.14	2.63	1.04	0.12	0.59	9.00	42	1.90

APPENDIX

Exchangeable bases, pH, etc. of soils—concld.

Depth in ft.	Clay percentage	$CaCO_2$ percentage	*p*H	M. E. Exchangeable bases per 100 gm. of soil					B.E.C. per 100 gm. clay	$\frac{SiO_2}{Al_2O_3}$
				Ca	Mg	K	Na	Total ex. cap.		
Per-humid				***Taliparamba—Madras***						
0—1	29.59	—	4.66	1.7	1.1	0.17	0.4	9.2	31	1.64
1—2	49.49	—	4.45	1.2	1.0	0.13	—	8.2	16	1.74
2—3	45.99	—	4.37	0.9	0.9	0.17	—	6.7	14	1.74
3—4	46.86	—	4.33	0.5	0.5	0.12	—	6.1	13	1.86
4—5	36.97	—	4.16	0.6	0.4	0.19	—	5.2	14	1.81
Calcareous				***Peshawar—N.W.F.P.***						
0—1	11.90	18.20	7.90	4.65	0.19	0.14	0.10	6.85	58	2.62
1—2	11.87	19.50	8.37	5.80	0.55	0.18	0.35	6.80	59	2.72
2—3	13.99	18.80	8.35	5.25	0.52	0.19	0.90	7.10	50	2.98
3—4	12.34	17.93	8.94	5.60	0.20	0.24	0.70	6.90	55	2.88
4—5	15.42	19.50	8.57	5.70	0.61	0.23	0.87	6.80	44	2.49
				Sakrand—Sind						
0—1	9.37	11.90	7.69	6.50	0.53	0.53	1.06	9.35	100	2.61
1—2	5.11	10.93	7.80	5.55	0.35	0.22	1.07	7.25	141	2.58
2—3	5.89	8.40	7.23	6.66	0.43	0.18	1.66	7.60	129	2.52
3—4	10.10	11.10	7.24	8.85	1.27	0.91	0.20	10.45	103	3.00
4—5	4.82	11.50	7.27	8.93	1.63	1.48	2.53	10.10	209	2.40
				Karachi—Sind						
0—1	6.57	22.45	7.14	10.35	0.62	0.66	—	17.90	292	3.33
1—2	6.25	24.27	7.73	9.50	0.74	0.47	—	14.30	228	3.40
2—3	6.86	25.80	7.52	3.75	0.40	0.52	—	11.00	160	3.42
3—4	6.78	19.00	7.32	3.60	0.25	0.52	—	10.70	154	3.68
4—5	6.06	23.00	7.40	16.05	0.69	0.72	—	18.10	298	3.52
				Padrauna—U. P.						
0—1	9.78	37.40	7.69	7.30	0.84	0.08	0.14	10.05	102	3.21
1—2	7.00	49.00	7.88	5.53	0.32	0.08	0.64	5.35	76	3.55
2—3	6.48	51.75	7.93	1.40	0.23	—	—	2.51	38	3.48
3—4	3.36	52.50	7.96	1.50	0.31	—	0.14	2.70	80	3.40
4—5	3.20	55.75	7.83	1.10	0.41	—	—	2.28	56	3.77
				Pusa—Bihar						
0—1	5.62	35.99	7.28	1.70	1.01	0.23	0.15	3.23	57	2.55
1—2	7.65	39.66	7.44	3.35	2.34	0.20	0.08	5.25	68	2.90
2—3	5.83	40.53	7.21	2.15	1.65	0.24	0.23	4.75	81	2.93
3—4	4.22	44.67	7.28	2.40	2.06	0.06	0.56	3.38	80	4.01
4—5	5.82	47.86	7.45	2.05	2.29	0.10	0.47	3.20	54	3.53

COMPARATIVE STUDIES ON INDIAN SOILS

IV. MECHANICAL ANALYSIS OF SOIL PROFILES

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(With two text-figures)

Majority of Indian soils are believed to be of transported nature. In arid regions, where rivers, controlled by specific geographical conditions, have long ceased to have any influence, wind continues to play an active part in transporting and retransporting soil from one region to another. Thus the present day Rajputana, which was once a fertile portion of Indus valley is now a tract of barren sand and salt which are still being carried by the strong western wind from the Rann of Cutch [Blanford, 1876; Holland, 1908; Holland and Christie, 1909; and La Touche, 1911]. The great north Indian alluvial mantle subjected at various regions to different climatic conditions had been derived from the Himalayan system by sedimentation from the great rivers Indus, Ganges and Brahmaputra. The type of soil building through transport of mud and silt from the plains of the United Provinces to the lower regions of Bengal is still going on [Vijayaraghavacharia, 1939]. Even the oldest tract of India, the Deccan lands are not exempt from this process. For centuries the soils had been carried far and wide by wind and rains from where they had been formed so much so that the nature of the parent material of most of the soils remain untraced even today except in certain sporadic cases.

Soils of India thus being mostly of a transported nature, depth distribution of clay in the profile is of not much use for the interpretation of profile development and the resulting profile morphology. The relative proportions of groups of different particle sizes namely clay, silt and sand are however useful in classifying the various soils and their profiles on a textural basis.

The object of mechanical analysis of soils is to obtain information on particle size and to visulize the probable field behaviour of the soil. During the present work, mechanical analysis of several virgin soils from different parts of India were carried up to a depth of 5 ft. The object was to make an attempt to classify Indian soils on textural basis, to study aggregation of clay under different climatic conditions, to study distribution of clay or its movement, if any, along the profile and to draw some general conclusions about the effect of different agencies on the mechanical composition of the soils of India.

Methods of analysis

The mechanical analysis of the soils were done by Puri's [1929] NaCl dispersion method. The dispersion was secured by treatment with NaCl to convert the clay into sodium saturated condition and the grading of the particles was done by the pipette method.

For determination of water stable aggregates 15 gm. of soil were boiled with 150 c.c. of water for 15 minutes and the mixture was shaken in an end over end shaker for six hours. Total volume of the soil water suspension was then made up to 1,500 c.c. and the grading was done by the pipette method. In this case, only clay fraction was pipetted as the most active participant in the soil aggregation is clay. The difference between total clay as determined by the NaCl dispersion method and that determined by the simple water dispersion method was taken to be the amount of the clay present in an aggregated condition or the temporary or false aggregation as it is usually termed [Tiulin, 1928].

The results of analysis are given in Appendices I and II.

Classification of the soils on the basis of the mechanical fractions

An examination of the data for analyses involving NaCl dispersion shows that the values do not check with the visual textural designations such as sandy loam and clay loam. This is because soils rich in sesquioxides may show high clay contents by analysis and yet lack clayey texture and feel; also under the influence of prevailing climatic conditions, the natural aggregation of clay particles may be sufficiently strong to make the aggregates of clay particles behave like coarser particles.

It is, however, seen that in the majority of the soils the clay contents of the profiles by NaCl dispersion show some order increasing from first to third foot where usually it is maximum. A further examination of the data shows three types to occur—(a) those in which clay percentage decreases down the profile, e.g. Padrauna and Rangpur; (b) soils in which clay content increases down the profile, e. g. Gurdaspur and Chinsura; and (c) soils in which the percentage of clay is maximum at the third or fourth foot below the surface. A large number of soils comes under this group.

The relatively lower content of clay of the surface soil compared to the maximum clay content of the soils of the third and fourth foot (Lahore, Gurdaspur, Shahjahanpur, Makrera, Sylhet and Sirsi) by the NaCl dispersion method indicates eluviation. This may be the result of variations in the composition of successive alluvial deposits or of the nature of the processes subsequent to deposition. A reference to climatic factors shows that soils in the arid and the semi-arid regions having low rainfall have also low clay contents, e.g. those of Peshawar, Lyallpur, Sakrand and Makrera. The Lahore and Haripur soils are exceptions. The soils of Gurdaspur and Shahjahanpur which are under comparatively higher rainfall conditions have also a higher clay content. Rainfall has undoubtedly an important function in the weathering of soil but the original parent materials from which the transported soils were derived is also an important factor. For instance, the black soils from Akola, Labhandi, Powarkhera and Indore have a higher clay content although the rainfall is not so high. The higher clay content of Haripur soil although formed under arid conditions may be attributed to its development mainly from slates. Again, Padrauna soil, receiving almost the same amount of rainfall, is a sandy loam.

Textural variations are more marked in Assam and Bengal soils. In these two provinces, the soils are mainly alluvial and the variations in mechanical composition are predominantly determined by the nature of the deposited materials and the relief of the land. Thus Jorhat soil is much more sandy than Sylhet soil. Jorhat soil was formed by the deposits of the river Brahmaputra and being located at a higher level causes the coarser materials to be deposited. Sylhet receives the deposits laid down by the Surma River and being placed at a much lower level gets the finer deposits in large quantities. The higher content of clay down the profile in Sylhet explains also the occurrence of numerous swampy lands. Similar factors operate in distinguishing the Bengal soils from Rangpur and Chinsura. Here the differences in the nature of the deposits coming from different sources become more important.

Aggregation of clay

The significance of mechanical analysis by itself is small in throwing light on the processes of soil formation but it is of importance in giving an insight into the physical properties of soils, *in situ* and the aggregation resulting from action of chemical factors under the physical influences of the climate. The formation of aggregates, that is, the formation of compound clay particles which function as coarser particles can take place under the following conditions: (1) cohesion between clay particles, (2) cementing effect of organic matter and bacterial slime, (3) cementing effect of calcium compounds, and (4) cementing by oxides of iron and aluminium present in varying degrees of dehydration. All these factors are influenced by the prevailing climatic conditions. An idea of the amount of aggregation in various soils will be obtained from the data given in Appendix II.

Baver and Harper [1935] observed low aggregation in desert soils and podsols occurring respectively in arid and wet regions whereas a high aggregation was noticed in

chernozems which usually occur in semi-arid and semi-humid areas. The average percentage aggregation of clay $\frac{[Total\ clay\ (NaCl)—Clay\ (water)]}{Total\ clay} \times 100$ in the soils studied by us, excepting 3 out of 34, has been found to be 74.65 ± 1.78 with a coefficient of variation 13.06. This shows, contrary to the observations of Baver, that aggregation in Indian soils is not effected by climatic conditions.

Influence of climate on the formation and movement of clay

The influence of climate on the formation and movement of clay has been referred to earlier. This is further exemplified by the data given in Tables I and II where the average values of the clay, silt and sand fractions have been tabulated according to the climatic divisions (Table I) and the colour of the soil (Table II).

The average data given in Tables I and II, are represented graphically in Figs. 1 and 2.

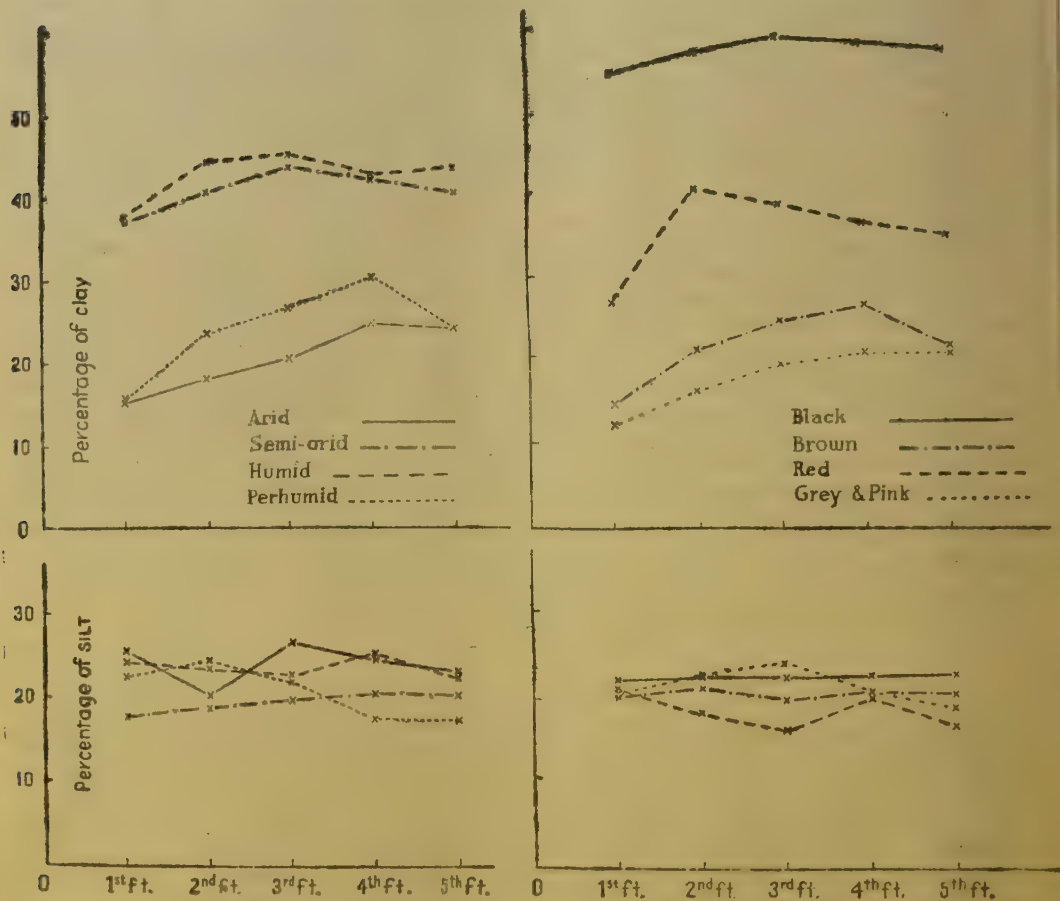

Fig. 1. Fig. 2.

Figs. 1 and 2. Percentage of silt and clay.

TABLE I

Mechanical fractions of soils under different climatic conditions

Depth in ft.	Clay percentage	Silt percentage	Sand percentage
	Arid (4 soils)		
0—1	15.20	24.61	60.19
1—2	18.14	25.14	56.72
2—3	20.46	26.84	52.70
3—4	24.86	24.63	50.51
4—5	24.01	23.06	52.93
	Semi-Arid (15 soils)		
0—1	37.06	17.68	45.26
1—2	40.84	18.71	40.45
2—3	43.86	19.76	36.38
3—4	42.14	20.61	37.25
4—5	40.56	20.33	39.11
	Humid (11 soils)		
0—1	37.68	24.08	38.24
1—2	44.67	23.33	32.00
2—3	45.06	22.87	32.07
3—4	42.70	25.14	32.16
4—5	43.70	22.61	33.68
	Per-humid (8 soils)		
0—1	15.52	22.62	61.86
1—2	23.87	24.44	51.69
2—3	26.73	21.96	51.31
3—4	30.14	17.39	52.47
4—5	24.03	17.06	58.91

TABLE II

Mechanical fractions of soils grouped according to their colour

Depth in ft.	Clay percentage	Silt percentage	Sand percentage
	Black (13 soils)		
0—1	54.49	22.17	23.34
1—2	56.90	22.46	20.64
2—3	58.53	22.42	19.05
3—4	57.73	22.56	19.71
4—5	56.71	22.71	20.58
	Brown (12 soils)		
0—1	14.90	20.58	64.52
1—2	21.31	22.66	56.03
2—3	24.58	24.00	51.42
3—4	26.27	20.90	52.83
4—5	21.05	20.34	58.61
	Red (4 soils)		
0—1	26.79	21.02	52.19
1—2	40.24	18.16	41.60
2—3	38.08	16.09	45.83
3—4	35.93	20.01	44.06
4—5	34.29	16.42	49.29
	Grey and pink (7 soils)		
0—1	12.38	20.23	67.39
1—2	16.34	21.20	62.46
2—3	19.45	19.93	60.63
3—4	20.77	20.93	58.30
4—5	20.21	18.63	61.16

In both arid and per-humid climates maximum clay content occurs at the fourth foo The difference between the maximum and the minimum within the profile is greater in th case of per-humid than in the case of arid regions. This may be due to mechanical downwar movement of the clay with persistently greater rainfall.

Black soils containing a high amount of clay show little variation in their content from depth to depth. It is probably due to the absence of free movements of the cla particles to any appreciable extent. The rest of the soils are characterized by low cla contents and the evidence of illuviation of clay along the profile is marked.

Silt, however, does not show variation in the profile to the same extent as cla excepting a few soils, its percentage varies on an average from about 15 to 35 and in some of the profiles the variation is reverse of that observed for clay. The sum of the per centages of sand fractions varies almost inversely to that of clay.

Summary

Data of mechanical analysis of 43 soil profiles obtained from different parts of India show that the soils could be classified into three groups: (1) soils where clay content decreases down the profile—number of such soils are small; (2) soils where clay content increases down the profile; and (3) soils where maximum clay content is observed in the third or the fourth foot depth. Majority of Indian soils fall under this last group. There are indications which show that the clay moves down mechanically to lower depths from the surface.

The amount of clay aggregated is not influenced by the prevailing climatic conditions under which the soils have been developed.

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Appendix 1

Mechanical analysis of soil profiles by NaCl dispersion

Profile No.	Station	Depth in ft.	Percentage of moisture at 100°C.	Percentage of clay 0.002 mm. and below	Percentage of silt 0.002 — 0.02 mm.	Percentage of very fine sand 0.02—0.05 mm.	Percentage of other sands above 0.05 mm.
1	Peshawar (Tarnab Farm), N. W. F. P. ...	0—1	1.07	11.90	30.85	31.70	25.55
		1—2	0.96	11.87	24.85	39.49	23.79
		2—3	1.07	13.99	28.52	34.80	22.69
		3—4	0.88	12.34	32.41	27.38	27.87
		4—5	0.83	15.42	15.14	30.08	39.36
2	Haripur Hazara, ... N. W. F. P.	0—1	1.37	21.10	44.61	19.47	14.82
		1—2	1.76	28.80	42.75	16.10	12.36
		2—3	2.22	30.48	47.45	9.81	12.25
		3—4	2.32	35.21	46.27	6.55	11.97
		4—5	2.51	36.10	42.26	11.49	10.15

APPENDIX I

Mechanical analysis of soil profiles by NaCl dispersion—contd.

Profile No.	Station	Depth in ft.	Percentage of moisture at 100° C.	Percentage of clay 0·002 mm. and below	Percentage of silt 0·002 – 0.02 mm.	Percentage of very fine sand 0.02—0·05 mm.	Percentage of other sands above 0.05 mm.
3	Lahore, Punjab ...	0—1	1.73	17.66	31.76	19.12	31.46
		1—2	1.74	21.80	34.06	18.14	26.00
		2—3	1.09	26.86	35.06	15.78	22.30
		3—4	1.02	24.30	35.80	31.50	8.40
		4—5	1.19	19.14	32.02	23.84	25.00
7	Gurdaspur, „ ...	0—1	0.83	11.58	34.60	18.98	34.84
		1—2	1.36	20.65	39.15	19.03	21.17
		2—3	1.77	23.88	40.71	8.17	29.24
		3—4	1.86	24.01	37.74	15,75	22.50
		4—5	2.02	24.74	40.65	18.04	16.57
8	Kangra, „ ...	0—1	1.36	11.55	28.82	19.46	40.17
		1—2	1.15	13.75	23.66	15.51	47.08
		2—3	1.04	13.83	13.94	18.05	54.48
		3—4	0.96	11.51	14.27	16.75	57.47
		4—5	0.88	12.38	10.53	15.61	61.48
9	Lyallpur, „ ...	0—1	1.73	9.89	16.09	12.33	61.69
		1—2	1.74	12.40	15.30	19.60	52.70
		2—3	1.10	11.92	12,70	12.15	63.23
		3—4	1.02	13.84	10.81	13.82	61.53
		4—5	1.49	12.59	14.37	17.78	55.26
10	Mianwali, „ ...	0—1	1.35	13.58	13.18	6.28	66.96
		1—2	1.12	12.94	14.66	6.47	65.93
		2—3	1.10	12.13	11.92	7.68	68.27
		3—4	0.95	11.71	12.92	6.86	68.51
		4—5	0.62	7.24	10.67	4.83	77.26
11	Sakrand, Sind ...	0—1	0·87	9.37	31.14	30.43	29.06
		1—2	0.74	5.11	21.24	41.05	32.60
		2—3	0.77	5.89	19.10	30.90	44.11
		3—4	1.20	10.10	34.18	49.10	6.62
		4—5	1.30	4.82	34.65	42.12	18.41
12	Karachi (Malir Farm), Sind ...	0—1	0.76	6.57	8.06	3.18	82.19
		1—2	0.76	6.25	8.02	4.51	81.22
		2—3	0.83	6.86	9.68	5.49	77.97
		3—4	0.87	6.78	9.04	7.42	76.76
		4—5	0.78	6.06	8.47	6.06	79.41
13	Mirpurkhas, Sind ...	0—1	1.50	16.24	24.57	16.24	42.95
		1—2	1.26	18.43	27.85	17.82	35.90
		2—3	1.93	27.32	35.28	18.15	19.25
		3—4	1.75	38.68	28.50	8.96	23.86
		4—5	2.24	40.10	24.96	8.59	26.35
18	Shahjahanpur, U. P. ...	0—1	0.40	18.58	33.06	24.78	23.58
		1—2	1.70	20.40	30.26	22.54	26.80
		2—3	1.10	24.70	35.26	26.04	14.00
		3—4	1.60	25.14	35.18	25.02	14.66
		4—5	1.20	21.06	35.66	26.28	17.00
19	Pardrauna, U. P. (Low land) ...	0—1	1.01	9.78	14.02	38.60	37.60
		1—2	1.94	7.00	15.96	60.74	16.30
		2—3	2.22	6.48	15.82	58.00	19.70
		3—4	1.85	3.36	20.64	63.24	12.76
		4—5	1.94	3.20	27.10	64.80	4.90

APPENDIX I

Mechanical analysis of soil profiles by NaCl dispersion—contd.

Profile No.	Station	Depth in ft.	Percentage of moisture at 100° C.	Percentage of clay 0·002 mm. and below	Percentage of silt 0·002 — 0·02 mm.	Percentage of very fine sand 0.02—0.05 mm.	Percentage of other sands above 0.05 mm.
22	Ranchi, Bihar (Up land) ...	0—1	1.46	42.22	21.07	12.83	23.88
		1—2	2.20	41.31	18.52	14.17	26.00
		2—3	2.38	42.47	18.37	15.78	23.38
		3—4	2.37	35.72	27.40	12.18	24.70
		4—5	2.12	40.17	19.29	10.21	30.33
24	Nagpur, C. P. ...	0—1	7.30	59.55	19.63	5.87	14.95
		1—2	7.79	63.11	19.74	6.81	10.34
		2—3	8.33	66.32	21.38	4.80	7.50
		3—4	8.16	65.71	21.56	4.57	8.16
		4—5	7.84	64.46	21.92	5.21	8.41
25	Akola, „ ...	0—1	7.84	57.74	29.89	6.83	5.54
		1—2	8.18	60.48	26.30	7.70	5.52
		2—3	8.32	62.44	26.01	8.36	3.19
		3—4	8.48	64.14	23.89	8.46	3.51
		4—5	8.54	64.38	26.66	8.18	0.78
26	Waraseoni, „ ...	0—1	1.24	21.67	28.15	6.68	43.50
		1—2	1.86	40.35	26.49	12.23	20.93
		2—3	2.51	40.83	22.77	10.26	26.14
		3—4	2.31	34.40	27.84	12.28	25.48
		4—5	1.29	22.18	25.33	15.80	36.69
27	Labhandi, „ ...	0—1	6.57	60.07	25.78	5.74	8.41
		1—2	6.65	62.47	25.47	5.70	6.36
		2—3	6.61	61.14	23.10	4.30	11.46
		3—4	6.62	61.59	26.00	6.00	6.41
		4—5	6.38	60.61	23.46	5.38	10.55
28	Chandkhuri, „ ...	0—5 in.	1.76	18.12	24.33	14.17	43.38
		5—16 „	2.97	43.33	21.46	8.74	21.47
		16—28 „	3.18	36.36	17.97	7.48	38.19
		28—40 „	3.34	31.66	18.62	4.97	44.75
		40—52 „	3.23	38.65	12.61	6.49	42.05
		52—60 „	3.16	34.08	12.60	7.64	45.68
29	Kheri-Adhartal, „ ...	0—1	5.56	49.35	19.91	11.01	19.73
		1—2	5.90	51.01	19.55	9.24	20.20
		2—3	5.71	42.35	21.21	9.54	26.90
		3—4	3.95	31.86	19.16	8.54	40.44
		4—5	4.31	24.10	16.09	9.20	50.6
30	Powarkhera, „ ...	0—1	6.53	57.50	25.93	8.89	7.68
		1—2	6.29	52.28	27.42	9.14	11.16
		2—3	7.63	59.69	27.90	8.06	4.35
		3—4	7.60	51.98	27.30	8.53	12.19
		4—5	7.43	62.24	26.55	11.28	—
31	Indore, C. I. ...	0—1	8.00	65.40	19.25	12.50	2.85
		1—2	8.70	66.00	22.20	10.30	1.50
		2—3	8.80	64.50	23.00	12.30	0.20
		3—4	8.80	61.30	24.60	8.00	1.10
		4—5	7.10	47.30	30.40	8.60	13.70
32	Kharua, „ ...	0—1	6.64	52.70	22.71	11.14	13.45
		1—2	6.78	52.78	22.53	10.73	13.96
		2—3	6.65	54.84	23.14	9.00	13.02
		3—4	6.74	53.11	22.82	11.03	13.04
		4—5	5.24	44.32	27.44	10.13	18.11

APPENDIX I

Mechanical analysis of soil profiles by NaCl dispersion—contd.

Profile No.	Station	Depth in ft.	Percentage of moisture at 100° C.	Percentage of clay 0.002 mm. and below	Percentage of silt 0.002 — 0.02 mm.	Percentage of very fine sand 0.02—0.05 mm.	Percentage of other sands above 0·05 mm.
33	Makrera, Ajmere-Merwara ...	0—1	1.04	8.36	10.80	8.22	72.62
		1—2	1.39	13.67	11.12	7.94	67.27
		2—3	1.92	15.51	12.69	7.09	64.71
		3—4	1.59	14.79	19.08	11.23	54.90
		4—5	1.57	8.16	11.10	13.35	67.39
34	Tabiji, " ...	0—1	0.79	5.04	6.65	5.64	82.67
		1—2	0.84	6.05	7.06	4.44	82.45
		2—3	0.92	6.86	7.67	5.85	79.62
		3—4	1.05	9.30	11.32	6.06	73.32
		4—5	0.44	3.21	3.82	3.82	89.15
35	Jorhat, Assam ...	0—1	0.42	6.80	8.22	15.08	69.90
		1—2	0.52	8.98	17.38	12.48	61.16
		2—3	0.64	10.74	16.54	16.34	56.38
		3—4	0.60	9.78	13.30	17.20	59.72
		4—5	0.58	6.00	8.24	15.82	69.94
36	Karimganj, " ...	0—1	1.65	20.95	41.28	14.23	23.54
		1—2	1.85	19.97	42.38	14.67	22.98
		2—3	1.84	20.99	48.49	17.93	12.59
		3—4	1.47	16.04	34.71	18.47	30.78
		4—5	1.54	14.02	27.02	25.59	33.37
37	Sylhet, " ...	0—1	0 76	11.69	13.30	6.65	68.36
		1—2	1.55	32.30	33.72	11.78	22.20
		2—3	1.98	48.06	40.20	8.98	2.76
		3—4	3.37	81.08	14.35	1.45	3.12
		4—5	2.24	54.83	31.30	6.14	7.73
38	Dacca, Bengal ...	0—1	1.14	19.93	26.60	24.88	28.59
		1—2	2.18	39.55	25.75	18.93	15.77
		2—3	2.52	46.47	25.24	16.00	12.29
		3—4	2.58	44.96	27.51	15.40	12.13
		4—5	2.23	45.82	24.41	15.55	14.49
39	Rangpur, " ...	0—1	0.96	6.41	24.08	18.16	51.35
		1—2	0.70	5.08	19.98	16.96	57.98
		2—3	0.38	0.89	3.25	3.38	92.78
		3—4	0.12	1.43	0.95	1.14	96.48
		4—5	0.23	0.90	1.20	2.10	95.80
40	Chinsura, " ...	0—1	3.83	50.61	48.78	1.51	—
		1—2	3 69	53.72	45.39	1.33	—
		2—3	3.80	55.85	43.70	0.56	—
		3—4	4.01	58.47	36·81	1.60	3.12
		4—5	4.47	62.47	35.47	2.34	—
43	Sirsi, Bombay ...	0—1	1.77	17.23	12.57	11.85	58.35
		1—2	2.21	21.85	11.75	8.32	58.08
		2—3	2.09	27.80	10.70	7.88	54.54
		3—4	2.09	29.50	11.17	9.57	49.76
		4—5	2.41	21.29	9.94	8.80	59.97
48	Padegaon, " ...	0—1	9.58	74.75	16.36	1.11	7.78
		1—2	10.17	76.13	14.24	3.56	6.07
		2—3	9.92	76.92	14.87	2.66	5.55
		3—4	9.98	70.00	14.66	2.14	13.20
		4—5	10.48	74.29	15.41	1.90	8.40

APPENDIX I

Mechanical analysis of soil profiles by NaCl dispersion—concld.

Profile No.	Station	Depth in ft.	Percentage of moisture at 100° C.	Percentage of clay 0·002 mm. and below	Percentage of silt 0·002 — 0·02 mm.	Percentage of very fine sand 0·02—0·05 mm.	Percentage of other sands above 0.05 mm.
49	Surat, Bombay ...	0—1	8.31	47.10	19.50	2.20	31.20
		1—2	8.08	43.00	19.00	1.10	36.90
		2—3	8.26	43.10	18.30	7.70	30.90
		3—4	8.33	40.30	22.00	4.50	33.20
		4—5	8.34	43.00	17.70	4.10	35.20
50	Coimbatore, Madras ...	0—1	2.12	31.67	6.74	2.25	59.34
		1—2	3.30	37.26	7.49	1.25	54.00
		2—3½	3.47	38.74	12.53	3.52	45.21
		3½—5	2.78	26.95	12.75	4.52	55.78
51	Taliparamba, „ ...	0—1	2.00	29.59	26.11	7.85	36.95
		1—2	1.40	49.49	20.89	5.27	24.35
		2—3	0.84	45.99	17.35	8.65	28.01
		3—4	0.95	46.86	22.84	5.71	24.59
		4—5	0.82	36.97	23.83	6.92	32.28
52	Koilpatti, „ ...	0—1	7.47	62.90	11.24	3.67	22.19
		1—2	7.35	64.98	11.66	3.89	19.47
		2—3	5.96	72.52	12.12	2.98	12.38
		3—4	7.79	71.14	13.88	2.82	12.16
		4—5	7.65	71.69	10.40	3.03	14.88
54	Hagari, „ ...	0—1	2.52	43.95	19.49	3.49	33.07
		1—2	3.76	52.79	23.07	4.16	19.98
		2—3	3.82	59.06	21.83	5.20	13.91
		3—4	3.09	54.89	22 70	6.81	15.60
		4—5	3.47	52.21	25.48	8.91	13.40
55	Nandayal, „ ...	0—1	6.44	57.29	16.25	3.21	23.25
		1—2	6.91	61.45	17.40	5.16	15.99
		2—3	7.05	64.55	18.07	5.38	12.00
		3—4	7.18	65.94	17.88	4.09	12.09
		4—5	7.23	66.40	18.33	2.37	12.90
56	Samalkot, „ ...	0—1	1.30	24.88	16.61	9.12	49.39
		1—2	1.69	36.62	20.75	6.10	36.53
		2—3	1.60	36.18	19.31	5.49	39.02
57	Anakapalle, „ ...	0—1	0.84	9.48	7.26	5.85	77.41
		1—2	1.52	17.06	13.00	8.12	61.82
		2—3	2.06	24.10	14.70	8.58	52.62
		3—4	2.56	27.71	14.57	8.42	49.30
		4—5	2.51	26.28	11.70	8.83	53.19
58	Berhampore, Orissa ...	0—1	0.35	12.84	2.61	3.01	81.54
		1—2	0.87	31.79	1.61	4.03	72.57
		2—3	1.53	29.86	0.61	4.06	65.47
		3—4	1.82	30.45	11.49	6.25	51.31
		4—5	2.45	41.21	9.84	2.46	46.49
59	Pusa, Bihar ...	0—1	0.36	5.62	23.68	47.37	23.33
		1—2	0.66	7.65	31.01	43.49	17.85
		2—3	0.55	5.83	21.92	44.44	27.81
		3—4	0.52	4.22	24.93	56.69	14.16
		4—5	0.40	5.82	28.71	57.83	7.64
60	Delhi, I.A.R.I. ...	0—1	1.22	10.33	12.76	11.74	65.17
		1—2	1.34	18.45	12.39	11.55	57.63
		2—3	1.85	24.04	15.69	12.63	47.64
		3—4	1.93	24.27	15.50	13.26	46.97
		4—5	2.03	22.86	13.47	13.27	50.40

Appendix II

Clay contents of soil profiles by NaCl dispersion and simple dispersion by shaking with water

(Percentage of clays are in oven-dry basis)

Depth in ft.	Percentage of clay by NaCl dispersion (a)	Percentage of clay by simple dispersion (b)	a / b	Percentage of aggregation on clay
	1. Peshawar—Tarnab Farm			
1	11.90	4.55	2.61	62
2	11.87	3.39	3.50	—
3	13.99	4.03	3.47	—
4	12.34	4.00	3.08	—
5	15.42	3.44	4.49	—
	3. Lahore—Punjab			
1	17.66	5.53	3.19	68
2	21.80	6.13	3.56	—
3	26.86	8.43	3.19	—
4	24.30	5.55	4.38	—
5	19.14	6.98	2.74	—
	8. Kangra—Punjab			
1	11.55	4.61	2.51	60
2	13.75	3.12	4.40	—
3	12.53	4.16	3.25	—
4	11.51	3.55	3.24	—
5	12.38	3.35	3.70	—
	10. Mianwali—Punjab			
1	13.58	4.40	3.09	68
2	12.94	3.13	4.13	—
3	12.13	4.36	2.78	—
4	11.71	2.06	5.69	—
5	7.24	6.52	1.11	—
	12. Karachi—Sind			
1	6.57	4.01	1.63	39
2	6.25	5.61	1.12	—
3	6.86	5.01	1.37	—
4	6.78	4 93	1.38	—
5	6.06	4.61	1.32	—
	18. Shahjahanpur—U. P.			
1	18.58	2.02	9.18	89
2	20.40	11.34	1.80	—
3	24.70	8.39	2 95	-
4	25.14	6.79	3.71	—
5	21.06	4.42	4.76	—
	2. Haripur Hazara—N. W. F. P.			
1	21.10	6.46	3.27	69
2	28.80	7.98	3.61	—
3	30.48	9.68	3.15	—
4	35.21	10.24	3.44	—
5	36.10	11.32	3.19	—
	7. Gurdaspur—Punjab			
1	11.58	6.08	1.91	47
2	20.65	5.76	3.75	—
3	23.88	6.88	3.47	—
4	24.01	8.21	2.93	—
5	24.74	6.86	3.61	—
	9. Lyallpur—Punjab			
1	—	—	—	—
2	12.40	4.38	2.83	—
3	11.92	3.00	3·98	—
4	13.84	4.14	3.35	—
5	12.59	4.10	3.07	—
	11. Sakrand—Sind			
1	9.37	2.50	3.74	73
2	5.11	1.83	2.79	—
3	5.89	1.69	3.48	—
4	10.10	1.07	9.43	—
5	4.82	2.26	2.13	—
	13. Mirpurkhas—Sind			
1	16.24	4.00	4.06	75
2	18.43	5.11	3.61	—
3	27.32	3.56	7.67	—
4	38.68	4.24	9.13	—
5	40.10	4.06	9.87	—
	19. Padrauna—Low land			
1	9.78	2.41	4.06	76
2	7.00	2.38	2.94	—
3	6.48	0.38	17.05	—
4	3.36	1.68	2.00	—
5	3.20	0.48	6·63	—

Appendix II

Clay contents of soil profiles by NaCl dispersion and simple dispersion by shaking with water—contd.

(Percentage of clays are in oven-dry basis)

Depth in ft.	Percentage of clay by NaCl dispersion (a)	Percentage of clay by simple dispersion (b)	a / b	Percentage of aggregation on clay	Depth in ft.	Percentage of clay by NaCl dispersion (a)	Percentage of clay by simple dispersion (b)	a / b	Percentage of aggregation on clay
	22. *Ranchi—Bihar Upland*					24. *Nagpur—C. P.*			
1	42.22	9.98	4.23	76	1	59.55	9.90	6.01	83
2	41.31	9.47	4.34	—	2	63.11	12.65	4.99	—
3	42.47	9.25	4.59	—	3	66.32	10.97	6.05	—
4	35.72	6.74	5.30	—	4	65.71	12.22	5.38	—
5	40.17	9.82	4.09	—	5	64.46	16.17	3.99	—
	25. *Akola—C. P.*					26. *Waraseoni—C. P.*			
1	57.74	6.79	8.50	88	1	21.67	2.69	8.05	88
2	60.48	0.76	79.58	—	2	40.35	3.65	11.05	—
3	62.44	3.15	19.83	—	3	40.83	4.30	9.51	—
4	64.14	15.19	4.22	—	4	34.40	2.65	12.97	—
5	64.38	19.89	3.24	—	5	22.18	4.36	5.09	—
	27. *Labhandi—C. P.*					28. *Chandkhuri—C. P.*			
1	60.07	17.27	3.48	71	1	33.22	6.42	5.18	65
2	62.47	19.76	3.16	—	2	36.36	15.13	2.40	—
3	61.14	16.12	3.79	—	3	31.66	6.56	4.88	—
4	61.59	12.65	4.87	—	4	38.65	3·78	10.23	—
5	60.61	11.42	5.31	—	5	34.08	10.35	3.29	—
	29. *Kheri-Adhartal—C. P.*					30. *Powarkhera—C. P.*			
1	49.35	14.64	3.37	70	1	57.50	13.79	4.17	76
2	51.01	10.15	5.03	—	2	52.28	14.27	3.66	—
3	42.36	9.88	4.28	—	3	59.69	12.21	4.88	—
4	31.86	5.44	5.86	—	4	51.98	12.26	4.24	—
5	24.10	4.83	4.99	—	5	62.24	12.36	5.04	—
	31. *Indore—C. I.*					32. *Kharua—C. I.*			
1	65.40	7.59	8.62	88	1	52.70	12.00	4.39	77
2	66.00	9.94	6.64	—	2	52.78	9.37	5.63	—
3	64.50	7.01	9.20	—	3	54.84	7.36	7.45	—
4	61.30	8.66	7.08	—	4	53.11	7.27	7.31	—
5	47.30	7.00	6.76	—	5	44.32	6.51	6.81	—
	33. *Makrera—Ajmere-Merwara*					34. *Tabiji—Ajmere*			
1	8.36	3.51	2.38	58	1	5.04	1.43	3.53	72
2	13.67	4.52	3.03	—	2	6.05	1.73	3.49	—
3	15.41	4.17	3.69	—	3	6.86	2.02	3.39	—
4	14.79	2.45	6.04	—	4	9.30	3.59	2.59	—
5	8.16	1.78	4.57	—	5	3.21	2.17	1.48	—
	35. *Jorhat—Assam*					36. *Karimganj—Assam*			
1	6.80	0.20	33.99	97	1	20.95	5.36	3.91	74
2	8.98	1.71	5.22	—	2	19.97	3.90	5.12	—
3	10.74	0.14	76.74	—	3	20.99	4.43	4.74	—
4	9.78	0.72	13.58	—	4	16.04	3.94	4.07	—
5	6.00	0.02	300.00	—	5	14.02	3.48	4.03	—

APPENDIX II

Clay contents of soil profiles by NaCl dispersion and simple dispersion by shaking with water—concld.

(Percentage of clays are in oven-dry basis)

Depth in ft.	Percentage of clay by NaCl dispersion (a)	Percentage of clay by simple dispersion (b)	a/b	Percentage of aggregation on clay
		37. *Sylhet—Assam*		
1	11.69	2.54	4.60	79
2	32.30	13.32	2.42	—
3	48.06	5.12	9.38	—
4	81.08	0.75	108.10	—
5	54.83	4.83	11.35	—
		39. *Rangpur—Bengal*		
1	6.41	1.86	3.65	72
2	5.08	0.87	5.94	—
3	0.59	0.20	2.95	—
4	1.43	0.00	—	—
5	0.90	0.00	—	—
		43. *Sirsi—Bombay*		
1	17.23	2.70	6.38	84
2	21.85	0.10	218.50	—
3	27.80	0.00	—	—
4	29.50	—	—	—
5	21.29	—	—	—
		49. *Surat—Bombay*		
1	47.10	9.74	4.84	79
2	43.00	9.59	4 48	—
3	43.10	9.97	4.32	—
4	40.30	8.15	4.94	—
5	43.00	3.67	11.71	—
		Delhi—I.A.R.I.		
1	10.33	3.84	3.39	63
2	18.45	4.36	4.23	—
3	24.04	3.79	6.34	—
4	27.27	3.61	7.55	—
5	22.86	3.67	6.23	—
		38. *Dacca—Bengal*		
1	19.93	4.78	4.17	76
2	39.55	8.30	4.77	—
3	40.47	7.46	5.43	—
4	44.96	5.84	7.70	—
5	45.82	7.78	5.89	—
		40. *Chinsura—Bengal*		
1	50.61	13.52	3.74	73
2	53.72	13.75	3.91	—
3	55.85	15.39	3.63	—
4	58.17	14.03	4.17	—
5	62.47	18.91	3.30	—
		48. *Padegaon—Bombay*		
1	74.75	3.35	22.31	96
2	76.13	4.61	16.51	—
3	76.92	5.03	15.29	—
4	70.00	2.08	33.65	—
5	74.29	1.09	68.16	—
		59. *Pusa—Bihar*		
1	5.62	4.72	1.19	16
2	7.65	2.46	3.11	—
3	5.83	3.60	1.62	—
4	4.22	1.39	3.05	—
5	5.82	1.29	4.53	—

COMPARATIVE STUDIES ON INDIAN SOILS

V. SINGLE VALUE PHYSICAL CONSTANTS OF INDIAN SOILS

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The mechanical analysis of a soil gives the proportions of particles of different sizes from which the probable texture and related soil properties are deduced. Several soil workers have proposed from time to time different single value constants as characteristics to soil, as alternatives to mechanical analysis for assessing the probable field behaviour of a soil.

Hygroscopic coefficient [Crowther and Puri, 1924; Puri, Crowther and Keen, 1925; Puri, 1925], rate of evaporation at a given moisture content and wilting co-efficient [Alway, 1913; Shull, 1916], comparison of effective particle surface between different soils, dye absorption, heat of wetting and suction force [Haines, 1925; Haines, 1927] have been suggested as single value physical constants and have been shown to be unsuitable for use as indices of soil texture for one reason or another. Moisture equivalent has, however, been recommended by Cameron and Gallagher [1908]. Harding [1919] holds it to be an index of soil texture and consequently of its water relationships. The 'relative wetness' (soil moisture content divided by the moisture equivalent) has been used by Conrad and Veihmeyer [1929], who have shown the normal moisture capacity of the soil to be approximately the same as moisture equivalent. Briggs and Shantz [1912], Alway and Russel [1916], Smith [1917] and others have developed equations connecting moisture equivalent and clay content as found by the usual dispersion methods. As pointed out by Bodman and Mahmud [1932], Smith's equation is the only one based on actual observations while the others are derived.

The underlying idea in correlating mechanical analysis and single value constants has been to avoid the time consuming process of mechanical analysis, as a basis for physical specification. Sticky point requires no special or elaborate equipment for its determination and, if anything, is less empirical and more quickly determined. Sticky point has been used as an index of field capacity in irrigation surveys in Australia [Prescott and Poole, 1934]. Keen [1930] in a co-operative investigation reported considerable variation which ranged from 0.4 to 6.3. A new method for determining the moisture content at the sticky point has been reported by Feng Chao-lin [1939] and it is claimed to be simpler than Keen and Coutts' [1928] method.

Materials and methods

The soil profile samples mentioned in the previous sections of this series were submitted to the comparative study of moisture equivalent and sticky point in relation to the clay content of the soils. The sticky point was determined by Keen and Coutts' and by Feng Chao-lin's methods. Briggs and Maclane's [1910] method was used for the determination of moisture equivalent. The clay was determined after NaCl dispersion [Puri, 1929]. The data for clay content, moisture equivalent and sticky point determinations are presented in Appendix I.

Discussion of results

The errors in the methods (personal and method errors) were determined for three soils, each repeated on three consecutive days, and the following are variations observed :

	Keen and Coutts' method	Feng Chao-lin's method
Akola soil (K. C. Batra)	± 0.55	± 0.20
Labhandi soil (K. M. Mehta)	± 0.72	± 0.28
Nandayal soil (V. N. Prasad)	± 0.98	± 0.24

The correlation of the values for clay, moisture equivalent and sticky point have been made on the basis of climatic and colour grouping reported in the previous sections. The data for this are given in Appendices II and III.

It is seen from Appendix II that correlation is generally better in the case of soils from semi-arid and humid regions than in those from arid and per-humid regions. Clay and moisture equivalent values show closer correlation with the sticky point values by Feng Chao-lin's method than with those by Keen and Coutts' method. The error in the estimation of sticky point by the former method is also lower than that by the latter method.

An attempt has been made to obtain regression equations from the coefficients of correlation to see if the approximate value of the clay can be predicted with the aid of the values for the other two constants. In most cases, this has been found to be not possible.

The chief feature of the data reported is the lack of correlation or poor or negative correlation between clay and other physical values when classified on colour or popular basis and a more definite and higher correlation under claimatic basis. In the group of calcareous soils the correlation is definitely positive compared to any of the other groupings. The definite and positive correlation between moisture equivalent and sticky point indicates definite relationship between these soil characteristics indicating their usefulness as expressions of field behaviour. Sticky point can be a more reliable index than either mechanical analysis or moisture equivalent.

It is, however, to be noted that as a general method of soil examination, none of the single value constants can replace mechanical analysis as has been shown by various previous workers. They attributed the failure to the presence of large amounts of organic matter in the soils they investigated. Our results with Indian soils in which the organic matter is negligibly low, also point to the same direction, but for other reasons. In our opinion, one of the reasons is that the dispersion treatment previous to particle grading is so drastic that the fairly strong aggregation that obtains in the field is broken. Other factors, such as the cationic composition of the clay complex, nature and amount of water soluble salts are also responsible for the lack of correlation between clay content and soil properties.

Summary and conclusions

Several single value constants have been determined in the case of a large number of Indian soils and it has been found that as a general method of soil examination none of these single value constants can replace mechanical analysis of soils.

Sticky point, however, can be a more reliable index of soil field behavior than either the mechanical analysis or moisture equivalent.

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Appendix I

Values for clay, moisture equivalent, and sticky point of soils

Name of the place	Climatic region	Popular grouping	Percentage of clay	Moisture equivalent (Average of duplicated)	Sticky point	
					Feng Chao-lin method	Keen and Coutts' method
Peshawar ...	Arid	Calcareous	11.90	15.90	21.63	23.07
Lyallpur ...	"	Indogangetic alluvium	9.89	14.30	14.70	13.55
Sakrand ...	"	Calcareous	9.37	13.10	20.53	24.70
Haripur Hazara ...	"	Brown	21.10	24.07	25.28	23.80
Mianwali ...	"	Indogangetic alluvium	13.58	9.33	14.80	13.84
Mirpurkhas ...	"	"	16.24	15.12	20.35	18.85
Karachi ...	"	Calcareous	6.57	7.27	14.45	14.64
Lahore ...	Semi-arid	Indogangetic alluvium	17.60	16.80	18.34	18.46
Gurdaspur ...	"	"	11.58	19.35	19.85	19.54
Makrera ...	"	"	8.36	10.88	16.33	16.75
Akola ...	"	Black	57.74	36.31	33.78	24.34
Indore ...	"	"	65.40	26.20	33.45	32.80
Padegaon ...	"	"	74.75	36.60	50.75	53.27
Surat ...	"	"	47.10	25.30	34.95	31.66
Kharua ...	"	"	52.70	25.88	30.63	34.12
Koilpatti ...	"	"	62.90	52.57	42.14	50.54
Hagari ...	"	"	43.95	37.05	33.41	27.60
Nandayal ...	"	"	57.29	48.60	47.58	35.04
Coimbatore ...	"	Brown	31.67	18.40	23.99	19.40
Anakapalle ...	"	"	9.48	8.09	14.83	16.75
Tabiji ...	"	"	5.04	5.00	13.80	16.45
Berhampur ...	Humid	Indogangetic alluvium	12.84	7.40	10.60	10.34
Padrauna ...	"	Calcareous	9.78	22.20	23.16	28.30
Labhandi ...	"	Black	60.07	31.97	39.40	30.10
Powerkhera ...	"	"	57.50	30.78	33.59	27.73
Nagpur ...	"	"	59.55	28.60	40.15	33.10
Kheri-Adhartal ...	"	"	49.35	27.99	32.43	26.23
Samalkot ...	"	"	24.88	20.17	22.74	24.54
Shahjahanpur ...	"	Brown	18.58	7.10	12.81	18.33
Waraseoni ...	"	"	21.67	16.52	22.81	17.48
Ranchi ...	"	Red	42.22	15.60	18.38	22.25
Chandkhuri ...	"	"	18.12	21.51	21.00	20.60
Rangpur ...	Per-humid	Indogangetic alluvium	6.41	23.10	26.35	31.80
Chinsura ...	"	Black	50.61	28.78	30.99	37.34
Dacca ...	"	Brown	19.93	16.80	33.45	32.80
Karimganj ...	"	"	20.95	28.18	27.05	27.15
Jorhat ...	"	"	6.80	11.25	18.50	20.55
Sylhet ...	"	"	11.69	11.22	15.90	18.22
Kangra ...	"	"	11.55	20.17	24.80	25.81
Taliparamba ...	"	Red	29.59	32.85	30.36	38.95
Sirsi ...	"	"	17.23	16.25	21.27	21.03

Appendix II

Correlation between different variables on basis of climatic classification

Region	Variables for correlation	Coefficient of correlation	Amount of correlation	Significance of correlation	Regression equation
Arid	Clay (X) and moisture equivalent (Y)	+0.809	High positive	Significant at 5 per cent level	$X=0.701\ Y+2.73$
Semi-arid	do.	+0.830	do.	Significant at less than 1 per cent level	$X=1.44\ Y+1.12$
Humid	do.	+0.774	do.	do.	$X=1.734\ Y-2.13$
Per-humid	do.	+0.647	do.	Significant at 10 per cent level	$X=1.15\ Y-4.67$
Arid (a)	Clay (X) and Sticky point (Y) Feng Chao-lin	+0.576	High positive	Not significant at 1 per cent 2 per cent 5 per cent and 10 per cent levels	$X=0.18+0.66\ Y$
(b)	Clay (X) and Sticky point (Y) Keen and Coutts	+0.385	Moderately positive	—	—
Semi-arid (a)	do.	+0.970	High positive	Significant at less than 1 per cent level	$X=2.07\ Y-22.18$
(b)	do.	+0.850	do.	do.	$X=1.71\ Y-9.38$
Humid (a)	do.	+0.842	do.	do.	$X=1.79\ Y-10.91$
(b)	do.	+0.680	do.	Significant at 2 per cent level	$X=2.06\ Y-14.41$
Per-humid (a)	do.	+0.600	do.	Significant at 10 per cent level	$X=1.37\ Y-15.39$
(b)	do.	+0.670	do.	Significant at 5 per cent level	$X=1.205\ Y-14.74$
Arid (a)	Moisture equivalent (X) and Sticky point (Y)—Feng Chao-lin	+0,974	do.	Significant at less than 1 per cent level	$X=1.24\ Y-9.14$
(b)	Moisture equivalent (X) and Sticky point (Y)—Keen & Coutts	+0.639	do.	Not significant at 1 per cent, 2 per cent, 5 per cent and 10 per cent level	$X=0.69\ Y+1.10$
Semi-arid (a)	do.	+0.950	do.	Significant at less than 1 per cent level	$X=1.21\ Y-9.42$
(b)	do.	+0.780	do.	do.	$X=0.93\ Y-0.19$
Humid (a)	do.	+0.947	do.	do.	$X=0.83\ Y-0.19$
(b)	do.	+0.875	do.	do.	$X=1.15\ Y-6.27$
Per-humid (a)	do.	+0.690	do.	Significant at 5 per cent level	$X=0.91\ Y-2.25$
(b)	do.	+0.827	do.	Significant at less than 5 per cent level	$X=0.87\ Y-3.57$

APPENDIX III

Correlation between different variables on basis of popular grouping

Grouping	Variables for correlation	Coefficient of correlation	Amount of correlation	Significance of correlation	Regression equation
Calcareous	Clay (X)+Moisture equivalent (Y)	+0.662	High positive	Not significant at 1 per cent, 2 per cent, 5 per cent and 10 per cent levels	X=6.03+0.23 Y
Red	do.	−0.036	Negligible	—	—
Indogangetic alluvium	do.	−0.242	Low negative	—	—
Brown	do.	+0.586	High positive	Significant at 10 per cent level	X=6.57+0.64 Y
Black	do.	+0.460	do.	do.	X=35.10+0.60 Y
Calcareous (a)	Clay (X)+Sticky point (Y)—Feng Chao-lin	+0.830	do.	do.	X=0.09+0.47 Y
(b)	Clay (X)+Sticky point (Y)—Keen and Coutts	+0.658	do.	Not significant at 1 per cent, 2 per cent, 5 per cent and 10 per cent levels	X=3.84+0.25 Y
Red (a)	do.	−0.100	Low negative	—	—
(b)	do.	+0.230	Low positive	—	—
Indogangetic alluvium (a)	do.	−0.316	Moderate negative	—	—
(b)	do.	−0.447	do.	—	—
Brown (a)	do.	+0.551	High positive	Significant at 10 per cent level	X=2.13+0.67 Y
(b)	do.	+0.265	Low positive	—	—
Black (a)	do.	+0.765	High positive	Significant at less than 1 per cent level	X=10.17+1.23 Y
(b)	do.	+0.620	do.	Significant at 2 per cent level	X=27.13+0.82 Y
Calcareous (a)	Moisture equivalent (X)+Sticky point (Y)—Feng Chao-lin	+0.926	do.	Significant at 5 per cent level	X=1.50 Y−15.19
(b)	Moisture equivalent (X)+Sticky point (Y) Keen and Coutts	+0.914	do.	—	X=0.98 Y−7.60
Red (a)	do.	+0.954	do.	—	X=1.45 Y−11.53
(b)	do.	+0.921	do.	Significant at 10 per cent level	X=0.16+0.83 Y
Indogangetic alluvium (a)	do.	+0.911	do.	Significant at less than 1 per cent level	X=1.01 Y−3.30
(b)	do.	+0.882	do.	—	X=1.65+0.72 Y
Brown (a)	do.	+0.796	do.	—	X=0.88 Y−3.59
(b)	do.	+0.651	do.	Significant at 5 per cent level	X=0.91 Y−4.49
Black (a)	do.	+0.688	do.	Significant at less than 1 per cent level	X=1.83+0.85 Y
(b)	do.	+0.524	do.	Significant at 10 per cent level	X=14.75+0.53 Y

STUDIES IN GANGETIC ALLUVIUM OF UNITED PROVINCES

I. CULTIVATED SOILS OF UNAO DISTRICT

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A systematic soil survey of the different districts of the United Provinces has been in progress for some time with a view to study the adaptablity of different soil types to the growing of food crops and fodders and to study the suitability or otherwise of the land types to irrigation facilities now available. A large volume of data has been collected in regard to the genetical characteristics of the soils of the United Provinces and in the present contribution some selected profiles out of a total of 24 studied by us from the Unao district have been described from the point of view of their genesis.

The Unao district lies between 26.8° and 27.2° north latitude and 80.3° and 81.3° east longitude. It is bounded on the north by Hardoi, on the east by Lucknow, on the south by Rai-Bareilly, all of which belong to the Lucknow Division; and on the west by the river Ganges which separates it from the Cawnpore and Fatehpur districts. In its general aspect the district may be divided into two main divisions, viz. the low-lands or *tarai* lying along the banks of the Ganges and the uplands which extend eastwards from the high bank. Most of the agricultural lands lie on the uplands and *tarai* areas are of very little economic importance, being subjected to periodic inundations. Out of the pits reported in the present paper Hariharpur pit No. 1 is situated in the *tarai* area and the other pits on the uplands.

Literature

The greater part of Northern India is occupied by alluvial deposits of the Indus, Ganges, Jumuna, Brahmaputra and their tributaries, but work in India on these alluvial soils from the genetic point of view has been extremely meagre.

Soil survey work from the point of view of agricultural suitability has been carried out in India amongst others by Harrison and Iyenger [1934], Harler [1931], Viswanath and Ramasubrahmanyan [1928], Simkins [1933], Sahasrabudhe [1929], and Mukerji and and Mukerji [1942]. Amongst the studies of soils from genetic point of view mention may be made of the work of Basu and Sirur [1938] who have studied the soils of Nira right bank and Pravara canals in Bombay Presidency, of Mukerji and Das [1940] who have studied the foot hill soils of Himalayas in the United Provinces and of Mukerji and Agarwal [1943] who have studied the soils of the Bundelkhand tract of United Provinces. It will appear from the foregoing that soil survey of the greater part of Northern India from the genetic point of view had hardly been undertaken so far.

Meteorology

Complete meteorological records of the Unao district are not available. In order to give an approximate idea of the locality, the records of observations at Cawnpore are presented in Table I. Cawnpore lies next to the Unao district on the right bank of the river Ganges and the climate of both the places is very much similar.

TABLE I

Weather report of Cawnpore (Average of 10 years)

	Temperatures (Degrees F.)		Humidity (per cent)	Rainfall (inches)	Soil temperatures (Degrees C.)	
	Maximum	Minimum			8 A. M.	3 P. M.
January ...	73.0	44.0	75.7	0.41	13.5	16.1
February ...	77.7	49.7	72.0	0.37	16.1	18.6
March ...	90.7	57.7	43.7	0.19	20.8	23.3
April ...	99.9	68.2	34.1	0.39	26.6	28.7
May ...	105.9	79.6	44.0	0.22	32.6	34.3
June ...	101.1	81.4	59.4	2,40	32.7	34.1
July ...	92.5	79.1	84.5	10.13	29.0	30.3
August ...	89.2	78.1	85.9	9.5	27.4	28.9
September ..	91.1	74.4	80.0	6.7	26.9	28.9
October ...	92.0	65.9	65.0	0.32	24.1	27.1
November ...	84.7	53.2	61.0	0.02	19.7	23.2
December ...	74.3	46.5	73.3	0.74	14.3	17.6

Winters which are mild are usually frost free On an average the maximum temperature during the months of November, December, January and February remains at 77.2°F. and minimum at 48.4°F. A few showers of rain are experienced in winter, but total precipitation during the whole period is rarely more than 2 in. The month of November remains practically rain free. Humidity during this period in the year is about 70 per cent and soil temperatures remain sufficiently high. The months of March, April, May and June are marked for high temperatures along with strong and hot winds.

The maximum temperature often rises to about 115°F. or more in the month of May. Relative humidity becomes very low and soil temperature attains at times as high a value as 45°C. On the whole this is the most arid period of the year for this locality. Rains usually start in the last week of June and continue till the third week of September. During the rainy season, the atmosphere remains highly saturated with moisture. Largest precipitation occurs in July. This period remains extremely humid. After the rains, there is tendency for the maximum temperature to rise again for a short period.

We have thus one humid and one arid period alternating with each other every year, and these climatic changes are reflected in the soil profiles. Lang's [1920], rain factor for this locality is about 31.9, which shows the aridity of the climate of the locality. N. S. quotient of Meyer [1926] for this area is 96.4, which also shows that the climate will favour desert and semi-desert type of vegetation which are usually met with in arid tropics.

METHODS OF PROCEDURE

(i) *Survey technique.* The details of technique adopted by us for the survey of soils in the plains are briefly enumerated below. Pits at selected places were dug up to a depth of not less than 5 ft. and each pit was broad enough for an observer to go inside and note the visual characteristics and composition of the profile. Observation on structure, texture, colour, concretions, hardness, etc. together with reactions with phenophthalein, dilute hydrochloric acid and universal soil indicator were taken *in situ*, and samples were obtained for laboratory analysis from each horizon. Wherever horizon differentiation was not marked, samples were obtained from each foot depth. After air-drying, the colour, structure and texture were again studied for each horizon in air-dry and moisture saturated conditions.

(ii) *Analytical methods.* 2 mm. samples were used for the analysis detailed below. Mechanical analysis was carried out by the International method. As these soils are very poor in organic matter, pretreatment of the soils with hydrogen peroxide was, however,

omitted. Hydrochloric acid extract for the determination of insoluble residue, sesquioxides and alkaline earths was made by the Agricultural Education Association method [Crowther, 1931]. Acid and potash soluble silica were estimated by the International method [Sigmond, 1927].

In these soils no difficulty was experienced in washing the hydrochloric acid residue free of the acid, and there was found to be no need to add either sodium or ammonium chloride or nitrate. But considerable difficulty was experienced in washing the residue from potash digestion with distilled water free of alkalinity and chloride, as dispersion immediately took place and a part of the residue passed through the filter paper. We had, therefore, to wash the potash residue with 2 per cent pure sodium chloride solution free from alkalinity. For each estimation about 400 c.c. of 2 per cent sodium chloride was used. After many trials we are satisfied that this modification of the International method was very necessary at least for these soils.

From 1 : 5 soil water ratio, soil extract was filtered with the help of a Chamberlain filter candle. In this extract water soluble salts, carbonates, bicarbonates, sulphates and chlorides were estimated.

*p*H values were determined by colorimetric method with Clark & Lubb's standard indicators in 1 : 2.5 soil N. KCl extract and in doubtful cases these values were checked on a hydrogen electrode.

Organic carbon was estimated by the method due to Walkley and Black [1934]. Nitrogen was estimated by Kjeldahl's method after modification suggested by Bal [1925]. For the determination of water holding capacity Coutts' method was used [1935].

Clay was separated according to the method suggested by Robinson [Wright, 1939]. Ignited clay was fused with sodium carbonate and analysed as silicate.

For determining exchangeable bases, considerable difficulties were felt, as none of the methods were found quite suitable. After many trials the method noted below was adopted.

Ten grams of soil washed free of soluble salts were leached with normal ammonium acetate solution and total exchangeable bases were estimated as in Bray and Willhite's method [1929]. The amounts of exchangeable lime and magnesia were determined in 100 c.c. of the extract. In another 100 c.c. of ammonium acetate extract, after evaporation and ignition in dull red heat, potash was estimated by Piper's method [1934]. Exchangeable sodium was estimated by difference. In soils containing carbonates normal ammonium acetate extract gave high figures for base exchange capacity and Chapman and Kelly's [1930] method was found unsuitable due to the presence of carbonates. In the latter case exchangeable lime and magnesia were estimated by Hissink's [1923] sodium chloride method and sum of all the bases was tabulated as base exchange capacity.

Experimental

The area covered by the present survey belongs to the latter half of the upper reaches of the river Ganges. Although according to expectation, a large majority of these soils are loams, considerable areas of clay lands have also been encountered, and on this basis all the Unao soils can be classified into three major groups of sandy, loamy and clayey soils. Each of these textural units can further be classified into genetic groups, depending on the developmental characters revealed by the processes of eluviation and illuviation operating in the development of these soil profiles. Easily determined and by far the most important genetic character of the soils of Unao district is the variation of clay content in the different horizons. On this basis we have divided Unao soils into two main types, viz. soils where no signs of eluviation of clay are present and soils where eluviation of clay leads to the development of textural horizons. Although we have not met with any sub-type under the first main type, the second type has two sub-types as will be detailed presently. Besides these two types of soils we have another type of soils resembling some of the soils of the second group but certain peculiar features which necessitated their classification under a separate head. Thus we have four groups of cultivable soils belonging to three main types so far met with in the Unao district.

Type 1. The visual description of the first type of soils is given in Table II and the results of their mechanical analyses in Table III.

TABLE II

Visual description of the first type of soils

Name of pit	Depth	Description
Hariharpur pit No. I.	0-9 in.	Structureless loam and ash grey. There is some organic matter; carbonates and alkalinity practically absent.
	9 in.-2 ft.	Grey, lighter than above, structureless. Organic matter and carbonates absent. The soil extract gives no reaction to phenolphthalein.
	2 ft.-3 ft.	Sandy, yellowish grey, Organic matter absent, although there is a trace of carbonates.
	3 ft.-5 ft.	More sandy than above: yellowish grey; structureless. Organic matter and alkalinity absent.

TABLE III

Mechanical analysis of Unao soils—Type 1 (Hariharpur pit No. I)

Horizon	B_1	B_2	C_1	C_2
Depth ...	0-9 in.	9 in-2 ft.	2 ft.-3 ft.	3 ft.-5 ft.
Coarse sand percentage ...	1.65	3.03	9.73	7.49
Fine sand percentage ...	37.35	49.50	76.51	80.40
Silt percentage ...	38.75	31.80	8.75	7.95
Clay percentage ...	19.50	13.75	3.0	2.55
Moisture equivalent percentage ...	33.25	25.94	9.5	7.21
Organic carbon percentage ..	0.76	0.43	0.27	0.32
Total N percentage ...	0.098	0.056	0.028	0.028
C/N ...	7.7	7.7	9.6	11.4

The field observations on these soil profiles do not show any clear demarcation of the constituent horizons and signs of eluviation are practically absent. A slight trace of carbonates in the third horizon can at best be considered to be due to precipitation of carbonates round feebly developed nuclei. The soil colour is ash grey and the horizon differentiation has been based on the textural character of individual layer. These soils are confined to a narrow strip of land along the left bank of the river, extending up to a breadth of 4 to 5 miles at places.

Coarses and fractions of these soils are high as compared to other alluvial soils and the clay fraction is low, showing less mechanical disintegration. There is a general tendency for clay content to decrease from the surface downwards and fine and coarse sand to increase. Carbon/nitrogen ratio tends to increase in the lower layers due to relatively lower nitrogen content. The data on the analysis of hydrochloric acid extract of these soils are given in Table IV.

TABLE IV

Chemical analyses of Unao soils—Type 1 (Hariharpur pit No. I)

Horizon	B_1	B_2	C_1	C_2
Depth ...	0-9 in.	9 in.-2 ft.	2 ft.-3 ft.	3 ft.-5 ft.
Moisture percentage ...	1.20	0.7	0.40	0.14
Loss on ignition percentage ...	4.12	2.68	0.80	0.60
Silica soluble in KOH in bulk samples percentage ...	1.25	1.40	1.48	1.36
Insoluble matter in HCl percentage	82.46	83.07	92.05	91.60
HCl soluble silica percentage ...	0.596	0.556	0.564	0.560
KOH soluble silica percentage ..	7.40	6.54	3.27	3.13
Silica in column 6 to sum of KOH and HCl soluble silica ...	15.63	19.72	38.90	36.85
Fe_2O_3 percentage ...	3.60	4.20	2.80	3.00
Al_2O_3 percentage ...	6.53	5.42	2.48	2.43
CaO percentage ...	1.05	1.53	0.83	1.19
MgO percentage ...	0.65	1.56	0.84	1.10
Sulphates percentage ...	0.07	0.06	0.10	0.07

TABLE V

Composition of 'A-Complex'—Derived data—Unao soils—Type 1 (Hariharpur pit No. I)

Depth	0-9 in.	9 in.-2 ft.	2 ft.-3 ft.	3 ft.-5 ft
Horizon	B_1	B_2	C_1	C_2
SiO_2/Al_2O_3 ...	2.06	2.21	2.61	2.57
SiO_2/R_2O_3 ...	1.53	1.48	1.52	1.44
Al_2O_3/Fe_2O_3 ..	2.84	2.02	1.39	1.27

Moisture and loss-on-ignition figures decrease with depth as a result of lower clay content. HCl insolubles increase in bottom layers, suggesting less weathering in the lower horizons, and this fact is further corroborated by lower soluble silica in C horizons. Sesquioxides are lower in C horizons although alkaline earth metals are more or less similar in both the horizons.

Relative to alumina, appreciable amounts of silica seem to have been eluviated from the surface soil downwards in the profile. The first two horizons have the same SiO_2/Al_2O_3 ratio, but the ratio increases slightly in the last two horizons. The Al_2O_3/Fe_2O_3 ratios of first two horizons are higher than those found in the last two horizons. The ratios appear to run parallel to the clay contents. This together with the morphological characters and mechanical data indicate the immature character of the Hariharpur profile.

The data on water soluble salts of the profile are presented in Table VI and exchangeable bases in Table VII.

TABLE VI

Analysis of water extract of Unao soils—Type 1

Locality	Horizon	Depth	Total water soluble solids	In mg. per cent				*p*H
				Carbonate Na_2CO_3	Bicarbonate Na HCO_3	Cl_2	SO_4	
Hariharpur pit No. I	B_1	0-9 in	80	nil	40	1.42	16.46	7.8
	B_2	9 in.-2 ft.	70	nil	50	1.42	4.12	8.2
	C_1	2 ft.-3 ft.	70	nil	60	0.71	12.34	8.2
	C_2	3 ft.-5 ft.	130	nil	60	2.13	12.34	8.3

TABLE VII

Exchangeable bases of Unao soils—Type 1

Locality	Horizon	Depth	Total exchangeable bases (m. e. percentage)	As percentage of 'S'			
				Ca	Mg	K	Na
Hariharpur Pit No. I	B_1	0-9 in.	26.4	31.44	32.20	2.05	34.31
	B_2	9 in.-2 ft.	44.5	39.10	24.66	1.08	35.16
	C_1	2 ft.-3 ft.	15.2	31.58	46.05	2.63	18.74
	C_2	3 ft.-5 ft.	33.5	36.42	20.90	0.90	41.76

Tables VI and VII depict clearly certain important developmental characteristics of these soils. Water soluble salts consisting chiefly of bicarbonates and chlorides appear to have leached down from the surface horizons. Maximum accumulation seems to have taken place in the lowest layer. This is presumably due to the sandy nature of the profile. Carbonates are absent from the profiles, whereas sulphates do not show very clear sign of translocation to the lower horizons.

The *p*H values of Hariharpur pit No. I are not constant in all depths of the profile but are more alkaline in character in the lower horizons. This increase of *p*H may be associated with the higher content of bicarbonate in the lower horizons and the consistently alkaline character of the four horizons of Hariharpur pit No. I also seem to be due to higher bicarbonate.

Exchangeable bases in the lower layers of the horizons are higher than those in the upper layers. Exchangeable potash (as percentage of 'S') is very low and bivalent bases constitute more than 50 per cent of total exchangeable bases. Exchangeable sodium is much too high and the largest amount is found associated in the zone of accumulation of soluble salts.

The clay composition of these soils is given in Table VIII.

TABLE VIII

Clay analysis of Unao soils—Type 1

Locality	Horizon	Depth	SiO_2 percentage	Al_2O_3 percentage	Fe_2O_3 percentage	$\frac{SiO_2}{Al_2O_3}$	$\frac{SiO_2}{R_2O_3}$	$\frac{Al_2O_3}{Fe_2O_3}$
Hariharpur pit No. I ...	B_1	0-9 in.	47.12	26.64	13.46	2.997	2.267	3.099
	B_2	9 in.-2 ft.	48.00	26.42	12.68	3.079	2.357	3.261
	C_1	2 ft.-3 ft.	47.64	25.52	12.68	3.176	2.412	3.154
	C_2	3 ft.-5 ft.	38.00	22.75	15.05	2.831	1.900	2.367

On a joint consideration of the data presented in Tables III to VIII, one comes to the conclusion that the soils represented by this type show some signs of immaturity, since the soil forming processes have not yet stabilized in the profile.

Type 2A. By far the large majority of soils studied by us show that clay contents assume their maxima at varying depths in the profile, and after this maximum is reached, the clay content decreases like Type 1 described in the previous pages. Thus these soils invariably show three distinct textural horizons designated by us a A, B and C. Some of these show along with the eluviation of clay, an accumulation of calcium carbonate in the 'C' horizon. Consequently we encounter two sub-types of this

major soil group, and amongst these, soils without the zone of accumulation of calcium carbonate form the majority. Visual characters and the mechanical composition of a typical formation of such sub-type, having no accumulation of calcium carbonate, are detailed in Table IX.

TABLE IX

Visual characters of a formation having no calcium carbonate

Name of pit	Horizon	Depth	Description
Mallawan	A	0 in.-1 ft.	Reddish brown; structureless loam; alkalinity and carbonates absent; very poor in organic matter.
	B_1	1 ft.-2 ft.	Same as above.
	B_2	2 ft.-3 ft. }	Loam, heavier than above and more compact; grey with a trace of dark colour; carbonates and alkalinity absent.
	B_3	3 ft.-4 ft. }	
	C_1	4 ft.-4 ft. 9 in.	Sandy loam, with single grain structure; organic matter and alkalinity absent.
	C_2	4 ft. 9 in.-6 ft. 3 in.	Sandy loam, lighter than above; single grained structure; organic matter absent; slight effervescence with hydrochloric acid.

TABLE X

Mechanical analysis of Unao soils—Type 2 A

Locality	Mallawan					
Horizon	A	B_1	B_2	B_3	C_1	C_2
Depth	0-1 ft.-	1 ft.-2 ft.	2 ft.-3 ft.	3 ft.-4 ft.	4 ft.-4 ft. 9. in.	4 ft. 9 in.-6 ft. 3. in.
Coarse sand percentage ...	0.78	0.03	0.31	0.80	1.35	1.09
Fine sand percentage ...	67.02	60.99	60.77	62.50	70.04	77.50
Silt percentage ...	18.65	13.65	16.30	15.10	12.95	11.35
Clay percentage ...	13.10	18.05	21.55	20.25	14.60	9.8
Moisture equivalent percentage ...	12.67	11.36	29.18	22.21	21.25	26.16
Organic carbon percentage	0.14	0.21	0.43	0.50	0.72	0.50
Total N percentage ...	0.028	0.029	0.028	0.026	0.025	0.049
C/N ..	5.0	7.2	15.4	19.2	28.8	10.0

Soils possessing the characteristics similar to the profile described above occur in localities contiguous to the zone of occurrence of Type 1 and has an average breadth of about 20 miles comprising the whole of the highlands to the east of the flow of river Ganges.

Occurrence of small lime spots resembling star shaped white fungus mycellia are seen in the 'C' horizon in most of the profiles. The latter is one of the most outstanding secondary formation met with in the cases of profiles belonging to this sub-type and from this point of view there seems to be no great fundamental genetical difference between the two sub-types of this group. A higher clay content together with the highest amount of colloidal matter towards the lower layer of the B-horizon tend to impede proper drainage in these profiles This layer often has a width of about 3 ft., although we have many cases where a width of about 5-6 ft has been met with. The mechanical composition of the profiles indicates marked eluviation of clay from the A-horizons and data on moisture equivalent also suggest colloidal matter accumulation in the lower layers. These figures substantiate the observation on the visual characteristics of the profiles. Moreover, the figures for organic carbon and C/N ratios of the continguous layers of all the profiles studied show that organic carbon also is trans-eluviated into lower layers. Data on chemical analysis of the profile are given in Table XI.

TABLE XI

Chemical analysis of Unao soils—Type 2 A

Locality	Mallawan					
Horizon	A	B_1	B_2	B_3	C_1	C_2
Depth	0-1 ft.	1 ft.-2 ft.	2 ft.-3 ft.	3 ft.-4. ft.	4 ft.-4ft.9in.	4 ft.9in.-6ft. 3in.
Moisture percentage ...	0.52	1.05	1.28	1.38	0.95	0.67
Loss-on-ignition percentage ...	1.59	1.69	2.13	1.78	1.89	1.38
Silica soluble in KOH in bulk sample percentage ...	1.03	2.16	1.68	1.33	1.38	1.23
Insoluble matter in HCl percentage ...	88.46	85.78	82.90	83.60	84.20	85.98
HCl soluble silica percentage ...	0.438	0.530	0.510	0.470	0.470	0.306
KOH soluble silica percentage ...	5.65	6.41	8.22	9.01	7.22	5.32
Silica in column 6 to sum of KOH & HCl soluble silica ...	16.19	31.12	19.24	14.03	17.95	21.85
Fe_2O_3 percentage ...	2.76	3.24	2.40	2.74	2.20	1.76
Al_2O_3 percentage ...	5.76	7.07	9.86	8.91	10.04	8.76
CaO percentage .	0.25	0.19	0.26	0.26	0.30	0.25
MgO percentage ...	0.05	0.22	0.04	0.04	0.08	0.05

Moisture and loss-on-ignition figures are invariably higher in 'B' horizon. We have had already indications of higher carbon content in these layers from Table X. Insoluble matter in hydrochloric acid decreases in the B-horizon ; whereas, soluble silica tends to increase. Sesquioxides, specially alumina, show signs of eluviation from A-horizon and accumulation in B-horizon. Calcium oxide appears to have been leached out from the entire profile. The processes of eluviation and illuviation in these profiles will further be clear on an examination of the derived data in Table XII in respect of SiO_2/R_2O_3, SiO_2/Al_2O_3 and Al_2O_3/Fe_2O_3 ratios of the so-called A-complex of these soils.

TABLE XII

Composition of A complex—derived data—Unao soils—Type 2A

Locality	Horizon	Depth	$\frac{SiO_2}{Al_2O_3}$	$\frac{SiO_2}{R_2O_3}$	$\frac{Al_2O_3}{Fe_2O_3}$
Mallawan	A	0 1 ft.	1.79	1.37	3.27
	B_1	1 ft.-2 ft.	1.66	1.28	3.42
	B_2	2 ft.-3 ft.	1.50	1.29	6.44
	B_3	3 ft.-4 ft.	1.80	1.50	5.10
	C_1	4 ft.-4ft. 9in.	1.29	1.14	7 16
	C_2	4ft. 9in.-6ft. 3in.	1.09	0.96	7.81

From the figures of SiO_2/R_2O_3 ratios it is clear that more of the sesquioxides have been leached down as compared to silica. Of the two oxides, iron oxide seems to be less mobile than alumina, since the ratio Al_2O_3/Fe_2O_3 increases with depth and the

value in the C_2 horizon is more than double of that in the top horizon. The presence of feebly deposited iron oxide round about quartz particles in the soil profile lead further support to the above indication. From the joint study of these data, it is clear that weathering of the A-complex leads to a condition of silica and alumina leaching on a large scale in these profiles.

Data of water soluble salts are given in Table XIII and those of exchangeable bases in Table XIV.

TABLE XIII

Water extract analysis of Unao soils—Type 2A

Locality	Horizon	Depth	In mg. per cent					
			Total water soluble solids	Na_2CO_3	Na HCO_3	Cl_2	SO	*p*H
Mallawan	A	0-1 ft.	78	4	4	nil	12.35	7.2
	B_1	1 ft.-2ft.	56	3	3	nil	4.12	7.2
	B_2	2 ft.-3ft.	60	nil	3	nil	16.42	6.8
	B_3	3 ft.-4 ft.	42	nil	8	nil	nil	6.8
	C_1	4 ft.-4.ft.9in.	67	nil	4	nil	8.20	6.8
	C_2	4ft 9in.-6ft.3in.	305	nil	5	nil	172.4	7.8

TABLE XIV

Exchangeable bases of Unao soils—Type 2 A

Locality	Horizon	Depth	Total exchangeable bases m. e. percentage	As percentage of 'S'			
				Ca	Mg	K	Na
Mallawan	A	0-1 ft.	6.3	41.26	31.75	Trace	26.99
	B_1	1 ft.-2ft.	8.8	34.50	28.42	0.88	37.08
	B_2	2 ft.-3 ft.	10.5	37.20	23.81	Trace	38.99
	B_3	3 ft.-4 ft.	11.4	34.27	26.32	0 88	38.53
	C_1	4 ft.-4ft.9in.	9.8	33.20	25.51	Trace	41.29
	C_2	4ft.9in.-6 ft.3in.	6.9	56.61	36.23	Trace	7.16

The zone of accumulation of salts is found in the last horizon which corresponds with C_2 horizon of our soils. Chlorides seem to be absent from the profile as a whole. The highest amount of sulphate is found in the horizon where the highest accumulation of soluble salts occurs. Lower *p*H of this profile as compared to that of Type 1 is probably due to lower content of bicarbonates.

Exchangeable calcium has bee found to be invariably high in all the profiles studied, whereas, there is considerable fluctuation in exchangeable magnesium. The amount of exchangeable potash in these soils is rather too low in all the cases and in the Mallawan profile presented in the paper exchangeable potash is practically absent Exchangeable sodium increases in the B-horizon. It appears, therefore, that due to the high percentage of exchangeable sodium in the complex, B-horizon tends to become impermeable.

The data on clay composition of these soils are presented in Table XV.

TABLE XV

Clay analysis of Unao soils—Type 2 A

Locality	Horizon	Depth	SiO_2 Percentage	Al_2O_3 Percentage	Fe_2O_3 Percentage	$\frac{SiO_2}{Al_2O_3}$	$\frac{SiO_2}{R_2O_3}$	$\frac{Al_2O_3}{Fe_2O_3}$
Mallawan	A	0-1 ft.	26.10	40.24	17.16	1.10	0.87	3.67
	B_1	1 ft.-2 ft.	46.63	22.84	17.16	3.46	2.34	2.08
	B_2	2 ft.-3 ft.	30.53	42.23	16.37	1.23	0.98	4.03
	B_3	3 ft.-4 ft.	49.13	20.63	14.77	4.04	2.77	2.19
	C_1	4 ft.-4ft. 9in.	53.05	25.33	16.77	3.55	2.50	2.36
	C_2	4ft. 9in.-6ft.3in.	45.58	25.04	21.56	3.09	1.99	1.82

The profile studied at Mallawan shows that considerable leaching of silica has taken place from the surface soil of this profile. Although in general the average values of silica/alumina and silica/sesquioxide ratios increase with depth, the profile shows its silicious character throughout. It is clear from the foregoing considerations that weathering in these profiles tends to deplete the complex of silica.

The position arrived at from the general study of the data presented in Tables X to XV is that the forces leading to the development of types of soil formations represented by Type 1 profiles have been much more magnified in the formations found in Type 2 profile. We find in this case that organic carbon has invariably been eluviated into the lower horizons. Clay and colloidal matter have also been subjected to this process. Bicarbonates and sulphates have been either washed out from the profile as a whole or have gone down to the deeper layers in the profile. The complete absence of chlorides from the profiles is another evidence of the leaching processes. The character of exchangeable bases also, as a result of this leaching, has been considerably modified, so much so that in the case of the Mallawan profile we find almost complete absence of exchangeable potash. Exchangeable sodium at the same time shows gradual increase in value in the B-horizons. The chemical analysis of all soils belonging to this type show eluviation of sesquioxides from surface to the B-horizon ; lime also shows the same trend ; and silica arising both from silica decomposition and silica weathering indicates signs of eluviation from the surface soils. Although the behaviour in regard to magnesium oxide is rather erratic, we find its eluviation from the surface soils in Mallawan profile. The composition of the A-complex of the various horizons of these soils show intensive silica and alumina leaching.

Type 2 B. As has been stated earlier in the second sub-type we have the C-horizons differentiated from the rest of the profile by the accumulation of insoluble calcium salts in them. Such soils are met with further east of the localities where the foregoing sub-type occurs and are found at distances of more than 14 miles from the left bank of the present course of the river Ganges. These two sub-types occur together and almost under the same topographical conditions in many localities. The differences in the composition of the parent alluvial material appear, therefore, to be one of the predisposing causes leading to the development of this peculiar soil type. Descriptions of two typical profiles are given in Table XVI.

TABLE XVI

Descriptions of two typical profiles—Type 2B

Name of pit	Horizon	Depth	Description
Rahmatpur	A	0-1 ft. 4 in.	Grey structureless loam ; friable, alkalinity and organic matter absent ; carbonates present in traces.
	B_1	1 ft. 4 in.-2 ft. 6 in.	Structureless loam, grey slightly heavier than above, organic matter and alkalinity absent and carbonates present in traces.
	B_2	2 ft. 6 in.-2 ft. 9 in.	Structureless loam, whitish grey heavier than above, organic matter and alkalinity absent; lime *kankar* present in traces.
	C_1	2 ft. 9 in.-4 ft. 5 in.	Greyish white, structureless loam ; lighter than above ; slightly alkaline with marked amount of lime nodules present, organic matter absent.
	C_2	4 ft. 5 in.-5 ft. 6 in.	Greyish white, structureless sandy loam, large amount of lime nodules present, soil is slightly alkaline very poor in organic matter.
Sarauti	A	0-1 ft.	Light yellow loam, structureless but compact. Trace of carbonates present.
	B_1	1 ft.-1 ft. 8 in.	Light yellow heavy loam, carbonates present in traces, soil structure not pronounced but resembles clods.
	B_2	1 ft. 8 in.-2 ft. 4 in.	Light yellow loam, with lime nodules present in appreciable quantities. Alkalinity absent.
	C_1	2 ft. 4 in.-3 ft.	Same as above, but slightly lighter with large amount of lime nodules.
	C_2	3 ft.-3 ft. 8 in.	Light loam, greyish white with a yellowish tinge. Lime nodules present in marked quantities.

A thorough chemical, physico-chemical and mechanical study of this sub-type indicates to a great extent the extremely marked leaching in progress in the profiles represented by those studies at Rahmatpur and Sarauti villages. We find in this case as in the case of the first sub-type eluviation of clay, colloidal matter, organic carbon, silica arising both from silicate weathering and silicate decomposition, sesquioxides, alkaline bases, sulphates and chlorides. Therefore, we consider the soils presented in this sub-group to have all the essential dynamic characteristics of the soils presented under the first sub-group.

Type 3. Occurring in the same zone as Rahmatpur profile we have another type of soil formation which visually appears to have characters which differ somewhat fundamentally from those described in the foregoing pages. This soil-complex does not by any means occur over wider areas than the foregoing types and are found as isolated islands Visual description of a typical profile belonging to this type are detailed in Table XVII and data for mechanical composition, moisture equivalent and organic nitrogen and carbon contents are presented in Table XVIII.

TABLE XVII

Visual description of a typical profile—Type 3

Name of pit	Depth	Description
Ashakhera	0-1ft. 1 in.	Reddish yellow, loam, structureless.
	1 ft. 1 in.-2 ft. 3 in.	Same as above. Organic matter. Alkalinity and carbonates absent.
	2 ft. 3 in.-3 ft. 11 in.	Brownish yellow loam, heavier than above, with no pronounced structure.
	3 ft. 11 in.-4 ft. 8 in. 4 ft. 8. in.-5 ft. 4 in.	Loam, structureless, alkalinity and carbonates absent. Brownish yellow in colour.

TABLE XVIII

Mechanical analysis of Unao soils—Type 3

Locality	Ashakhera				
Horizon	A_1	A_2	B_1	C_1	C_2
Depth	0-1 ft. 1 in.	1 ft. 1 in.- 2 ft. 3 in.	2 ft. 3. in.- 3 ft. 11 in.	3 ft. 11 in.- 4 ft. 8. in.	4 ft 8 in.- 5 ft. 4 in.
Coarse sand percentage ...	1.65	0.54	0.37	0.79	0.54
Fine sand percentage ...	50.75	55.09	51.45	52.51	55.18
Silt percentage ...	16.00	12.00	13.75	11.90	15.15
Clay percentage ...	28.15	27.30	29.80	31.60	29.15
Moisture equivalent percentage ...	17.80	22.87	19.16	17.04	14.61
Organic carbon percentage ...	0.28	0.14	0.29	0.29	0.29
Total N percentage ...	0.053	0.039	0.027	0.035	0.036
C/N ...	5.3	3.7	10.6	8.2	7.9

Horizon boundaries were clear enough in the case of Ashakhera profile. In this case the soils had no structure and were reddish yellow in colour. The soils belonging to this group are mostly friable light loams.

In Ashakhera profile the clay content is sufficiently high but the soil is friable on the surface. There is a very slight indication of the translocation of clay to the lower horizons. The moisture equivalent figures in these soils are rather low and there is some indication of eluviation of organic carbon. The variation in clay content with depth was found to be silimar to that in the second type.

The results of chemical analysis of these soils are given in Table XIX.

TABLE XIX

Chemical analysis of Unao soils—Type 3

Locality	Ashakhera				
Horizon	A_1	A_2	B_1	C_1	C_2
Depth	0-1ft. 1in.	1ft.1in.-2ft. 3in	2ft.3in.-3ft.11in.	3ft.11in.-4ft. 8in.	4ft. 8in.-5 4in.
Moisture percentage ...	0.48	0.46	0.61	0.62	0.60
Loss-on-ignition percentage ...	1.99	1.64	1.11	2.23	1.71
Silica soluble in KOH in bulk samples percentage ...	2.67	2.96	2.46	—	3.94
Insoluble matter in HCl percentage ...	89.73	89.77	86.49	85.36	85.05
HCl soluble silica percentage ...	0.114	0.134	0.282	—	0.234
KOH soluble silica percentage ...	3.51	6.47	8.63	—	5.56
Silica in column 6 to sum of KOH and HCl soluble silica ...	73.76	44.85	27.61	—	67.93
Fe_2O_3 percentage ...	0.68	0.80	1.04	1.24	1.68
Al_2O_3 percentage ...	5.70	6.23	8.47	8.40	8.12
CaO percentage ...	0.15	0.14	0.15	0.14	0.14
MgO percentage ...	0.74	0.95	0.97	0.77	0.74

Hygroscopic moisture is higher in lower layers. Insoluble matter in hydrochloric acid decreases in the lower horizons. Silica soluble in 5 per cent potash are higher noi B-horizon. Particularly remarkable, however, is the high amount of silica arising out of soil decomposition in the first horizon of this profile. Iron and aluminium oxides seem to have been eluviated from the surface soils. Although on an average containing very low amunt of lime this ingredient does not show any great fluctuation between the different horizons Magnesium oxide, however, seems to have been eluviated to the second horizon.

The acid base ratios of A-complex of these soils are presented in Table XX.

TABLE XX

Composition of A-complex derived data—Unao soils—Type 3

Locality	Horizon	Depth	$\frac{SiO_2}{Al_2O_3}$	$\frac{SiO_2}{R_2O_3}$	$\frac{Al_2O_3}{Fe_2O_3}$
Ashakhera ...	A_1	0-1ft.1in.	1.07	1.00	13.14
	A_2	1ft.1in.-2ft.3in.	1.79	1.66	12.21
	B_1	2ft.3in.-3ft.11in.	1.78	1.65	12.77
	C_1	3ft 11in.-4ft.8in.	—	—	—
	C_2	4ft.8in.-5ft.4in.	1.21	1.00	0.76

In this profile we find leaching down of silica from A_1-horizons ; the A-complex of the surface horizon of this profile contains very low amount of silica relative to sesquioxides Al_2O_3/Fe_2O_3 ratio shows slight accumulation of alumina in surface soils. Like the pits studied at Hariharpur we have in these cases an evidence of leaching down of iron in the profile indicating slight tendency for podsolization.

Data on water extract of these soils are presented in Table XXI.

TABLE XXI

Analysis of water extract—Unao soils—Type 3

Locality	Ashakhera				
Horizon	A_1	A_2	B_1	C_1	C_2
Depth	0-1ft.1in.	1ft.1in.-2ft.3in.	2ft.3in.-3ft.11in.	3ft.11in.-4ft. 8in.	4ft.8in.-5ft.4in.
Total water soluble solids ... (in mg. per cent)	64	78	114	108	94
Na_2CO_3 (in mg. per cent)	nil	nil	nil	nil	nil
$NaHCO_3$ (in mg. per cent)	32.0	46.0	88.0	96.0	75.0
Cl_2 (in mg. per cent)	nil	nil	nil	nil	Trace
SO_4 (in mg. per cent)	24.70	4.12	4.12	8.24	12.35
pH	7.2	7.2	8.4	8.4	8.4

In Ashakhera profile water soluble salts show a zone of accumulation in the B-horizon. Bicarbonate shows high values in B_1 and C_1-horizons. Chlorides seem to be absent from the profile as a whole. The behaviour in regard to the sulphates is rather erratic. The difference in pH values between the A and B horizons of Ashakhera profile is very marked. This difference is due to the character of exchange complex of these soils, data on which are presented in Table XXII.

TABLE XXII

Exchangeable bases of Unao soils—Type 3

Locality	Horizon	Depth	Total exchangeable bases m. e. percentage	As percentage of 'S'			
				Ca	Mg	K	Na
Ashakhera	A_1	0-1ft.1in.	7.0	55.86	35.71	8.02	0.41
	A_2	1 ft. 1in.-2 ft. 3 in.	7.3	47.54	27.40	6.58	18.48
	B_1	2 ft. 3in.-3ft. 11 in.	14.1	21.56	14.19	2.80	61.45
	C_1	3 ft. 11 in-4ft. 8 in.	11.3	19.29	13.28	4.25	63.28
	C_2	4ft. 8 in.-5 ft. 4 in.	12.1	18.02	12.40	2.58	67.00

Particularly noticeable is the fact that A_1- and A_2-horizons of Ashakhera profile contain very low amount of total exchangeable bases, which consist of nearly 75.90 per cent of calcium and magnesium cations. The high amount of exchangeable sodium in B-horizon of this profile has been due to leaching of salty solution in the past. The absolute impoverishment of the A-horizon in regard to exchangeable sodium which differentiates this group from the others will be discussed later.

The composition of the clay fractions of this profile is given in Table XXIII.

TABLE XXIII

Clay analysis of Unao soils—Type 3

Locality	Horizon	Depth	SiO_2 percentage	Al_2O_3 percentage	Fe_2O_3 percentage	$\frac{SiO_2}{Al_2O_3}$	$\frac{SiO_2}{R_2O_3}$	$\frac{Al_2O_3}{Fe_2O_3}$
Ashakhera	A_1	0-1 ft. 1 in.	46.86	23.74	14.26	3.346	2.418	2.606
	A_2	1 ft. 1 in.-2 ft. 3 in.	46.18	28.58	14.62	2.738	2.064	3.060
	B_1	2 ft. 3 in.-3 ft. 11 in.	45.30	28.34	14.21	2.709	2.050	3.112
	C_1	3 ft. 11 in.-4 ft. 8 in.	13.74	60.04	13.86	0.388	0.338	6.782
	C_2	4 ft. 8 in.-5 ft. 4 in.	28.16	45.08	14.62	1.059	0.877	4.827

In this we find the largest amount of silica in A_1-, A_2- and B_1-horizons. In this profile the horizons which appear to have sesquioxidic character are the C_2- and C_1-horizons.

The foregoing tables make it clear that soils represented by profile studied at Ashakhera village are in fact "Degraded sodium or 'Soloti' soils". We find in these profiles slight eluviations of clay, colloidal matter, organic carbon, soluble silica, magnesia and sesquioxides, and a considerable enrichment of the clay complex in the lower horizons with sodium. The absence of exchangeable sodium in the surface soils and the presence of sodium bicarbonate in these profiles lead one, therefore, to the belief that sodium complex in the surface soils has been degraded. Since we did not find any exchangeable hydrogen in the surface soils it can further be assumed that hydrogen clay

which results according to the Sigmond's theory [1938] by hydrolysis of sodium clay has been decomposed into silica and sesquioxides. This assumption is further verified by a very low amount of total exchangeable bases in the surface soils.

Discussion

The present study of the soils of the Unao district in the United Provinces *inter alia* throws some very useful light on the dynamics of a part of the Gangetic alluvium which represents the soils of the major part of the central United Provinces.

The profile differentiations into marked horizons are absent in most of the soils of this region. In many cases, however, we have evidence of the existence of textural horizons. The C-horizons of most of these soils are very sandy. The largest amount of silica arising out of the soil decomposition is confined mostly to first two horizons. Silica soluble in 5 per cent KOH, i. e. silica arising from the weathering of silicates, is illuviated into B-horizons. Sesquioxides show signs of translocation from A-horizons, a tendency which is shared more or less by the alkaline earth minerals.

The total water soluble salt content in general of all the profiles are not very high. Bicarbonates and sulphates form the two chief anions of the water extract. The bulk of the cations in the water extract has been found to consist of sodium. A large percentage of exchangeable bases consists of calcium and its total with magnesium amounts to over 50 per cent of the total exchangeable bases in most of the cases. Exchangeable potash is extremely low, and there is an appreciable amount of exchangeable sodium in the complex. In all the cases we find the evidence of the increase of sodium cation of the complex in the B-horizons, and nowhere is its percentage less than 12. These soils are, therefore, mainly sodium soils but are conspicuous by the absence of any well developed structure in the B-horizon as has been met with in the sodium soils of other countries.

Clay analysis data presented in the body of the paper show curiously enough some very peculiar features. Silica/sesquioxide ratio for some of these soils is much too low, showing some resemblance to clay characteristics of laterites as pointed out by Martin and Doyne [1927]. But as will be shown presently these soils can by no means be classed as laterites, thus showing as has already been indicated by recent workers [Joachim and Kandian, 1941], the inapplicability of the ratios to a large variety of tropical soils. It becomes clear from the analytical data that the soil is subjected to intense disruptive action, which breaks down the clay complex and translocates the acidoid fraction.

The first sub-type of Type 2 has well developed horizons of eluviation and accumulation. From the visual descriptions it is clear that tendencies for the accumulation of calcium carbonate exist in the third horizon. The total water soluble salts, chlorides and sulphate all go to show the effect of leaching. The exchangeable complex shows signs of gradual enrichment in sodium cations even in the C-horizon. The clay complex generally shows signs of disruption on the surface and eluviation of silica. Although these conditions show solonetz features yet no typical solonetz structure is apparent. In some of the profiles of this type we have appreciable amount of soluble salts. We have, from a thorough consideration of all the data, classified these soils under the broad group of saline alkali soils, although the profiles represented in this paper in many respects have solonetz features. The predisposing causes leading to the development of saline alkali soils must have been a salinic condition of the surface soil in the past originating in the cases of alluvial soils of Gangetic alluvium from weathering of the soil itself.

In the second sub-group of Type 2, we find an accumulation of calcium carbonate in the form of *kankar* nodules in the C-horizon. All other features are more or less similar to those found for soils belonging to the first sub-type. The processes leading to the formation of the soils of the two sub-groups of Type 2 are not very dissimilar and the cause of the occurrence of the zone of lime accumulation in the case of one sub-type must, therefore, be assigned to differences in the parent materials themselves.

We have already given an account of the immature character of the soils represented by Hariharpur 1 profile. Here, however, it could be easily seen from the data

presented that the processes of soil formation tend to a development of soil type similar in essentials to that of salty alkali soils. In view of the fact that the exchangeable complex contains more than 12 per cent sodium, it seems that the first stage of soil formation, viz. the so-called saline soils of Sigmond's [1938] first stage has been absent in the dynamics of the development of Unao soils. This could be explained by the supposition that these sodium soils of Unao are the cumulative effect of salinization and desalinization processes taking place within the same year. The immature character of the soils of first type have been fully discussed earlier and these soils may be classified as immature salty alkaline soils.

The soil formation represented by profile from Ashakhera is different from other soils of Unao district by the existence of a number of peculiar features. The absence of sodium cation from the surface soils and relatively lower amount of total exchangeable bases in these horizons together with very high amount of exchangeable sodium in the sub-soils point to a state of degradation of sodium soils. Although in Ashakhera profile the absolute values of silica/sesquioxide ratios in contiguous horizons show resemblance to podsols, we have not in this particular case detected any hydrogen clay and the base exchange complex is highly saturated. The chemical analysis of these soils also show mobilization of soluble silica, sesquioxides and lime. We therefore consider, particularly in view of reddish brown colour of the surface soils and in view of the character of A complex, these soils to be a variety of tropical Red Loams arising out of the degradation of sodium soils.

Summary

1. The soils of Unao district forming a part of Gangetic alluvium and lying on the left bank of the river have been studied from the point of view of their mechanical composition, chemical characters, total and individual water soluble salts, composition of exchangeable complex and chemical character of colloidal clay. Three genetic types of soils have been found to occur in this area.

2. The first type has been classified as immature salty alkali soils. The soils belonging to Type 2 which occupy by far the largest part of Unao district have been classified into two sub-types as salty alkali soils without zone of accumulation of calcium carbonate and salty alkali soils with a zone of accumulation of calcium carbonate. The pedological characters of the third group of soils show signs of degradation and have been classified as degraded salty alkali soils.

3. It has been suggested from a thorough study of data that the frequent occurrence of alkalinity in the soils of Unao district has been due to downward leaching of salty solutions arising primarily from soil decomposition. It has also been suggested that sodium soils on further degradation tend to assume characters of zonal soil types.

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EFFECT OF STORAGE ON RAPE-SEED AND RAPE-OIL

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IMPROPERLY stored seed undergoes deterioration rapidly and yields a crude oil of inferior quality, and a poor crude oil, in turn, yields products of low quality. Similarly oil that has suffered deterioration, through improper storage, either gives a low output of low-quality products or is totally unfit for use in the preparation of high-grade products. Thus in any scheme aiming at the establishment of oilseed-crushing industry in India on sound lines, the question of proper storage of seed and oil must occupy the centre of the stage and claim priority of attention. Unfortunately the problem of proper storage of oilseeds and oil has so far remained neglected, and this paper contains the results of experiments to assess the effect of different lengths and methods of storage on the quality of rape seed as well as on the quality of the oil expressed from such differently stored seeds, and the effect of different lengths of storage on the quality of rape-oil itself.

The methods of analyses employed in connection with the studies reported in this paper were those given in the 1935 edition of *Methods of Analysis of the Association of Official Agricultural Chemists, U. S. A.*

*Both the writers are to be regarded as joint authors without anyone's seniority over the other.

EFFECT OF STORAGE ON SEED

Methods and material. As preliminary studies had shown that on storage under-dry, unripe and damaged rape-seed deteriorates rapidly, and as this fact is too well-known to oilseed traders and processing establishments to need any extensive experimental corroboration, such seeds were excluded from the present studies. Consequently only dry, fully ripe, sound and fresh seeds of ***toria*** (*Brassica campestris* L., var *toria* D. and F.), brown-seeded ***sarson*** (*B.campestris* L., var. *dichotoma* Watt.), yellow-seeded ***sarson*** (*B. trilocularis* H. f. and T.) and ***raya*** (*B. juncea* H. f. and T.), which all are commercially designated as 'rape-seed', were employed in these studies The seeds were stored in the laboratory in lidless metallic containers and in gunny bags to simulate bulk and bag storage of trade, respectively. The experiment was carried out for a period of two years, longer period having been considered unnecessary in view of the fact that normally there will be no need for oilseed-crushing establishments to carry stocks of rape-seed for more than a year, i. e. from one harvest to another.

Samples from the aforesaid two differently stored lots of seeds were withdrawn at four-monthly intervals and small portions thereof analysed for their oil and nitrogen contents. Further determinations on the oil expressed from the remaining portions of seed-samples were made in respect of specific gravity at 15.5°C., acid value, saponification value and iodine value. The figures obtained from these analyses were compared with those obtained from similar determinations made on the seeds under study at the time of starting the experiment.

Results and conclusions. Only the final figures obtained at the end of two years' storage have been given in Table I, those for intermediate periods of storage having been excluded as they exhibited no marked differences and would thus have unnecessarily increased the bulk of this paper. Alongside these final figures, those obtained in respect of original seed have also been given for comparison.

TABLE I

Effect of storage on rape-seed

Name of oilseed	Method and period of storage	Results of analyses					
		Seeds		Oil freshly expressed from seeds			
		Percentage of oil	Percentage of nitrogen	Specific gravity at 15.5°C.	Acid value	Saponification value	Iodine value
Toria	Fresh, original sample	44.24	2.98	0.915	1.36	180.6	104.5
	Stored for 2 years:						
	(a) in bulk in lidless containers	44.79	2.76	0.915	1.88	178.4	102.7
	(b) in gunny bags	44.98	3.15	0.915	1.70	179.7	102.3

TABLE I

Effect of storage on rape-seed—concld.

Name of oilseed	Method of period of storgae	Results of analyses					
		Seeds		Oil freshly expressed from seeds			
		Percentage of oil	Percentage of nitrogen	Specific gravity at 15.5°C.	Acid value	Saponification value	Iodine value
Brown-seeded *sarson*	Fresh, original sample	48.83	2.83	0 915	0.82	186.4	100.9
	Stored for 2 years :						
	(a) in bulk in lidless containers	48.04	2.97	0.915	0.77	188.8	102.8
	(b) in gunny bags	48.44	2.76	0.914	1.09	187.5	98.2
Yellow-seeded *sarson*	Fresh, original sample	48.48	3.25	0.914	0.82	191.3	101.6
	Stored for 2 years:						
	(a) in bulk in lidless containers	48.42	3.15	0.915	0.70	188.5	101.3
	(b) in gunny bags	48.06	3.22	0.915	0.87	182.1	98.8
Raya (L-18)	Fresh, original sample	40.50	3.67	0.915	2.23	193.1	106.1
	Stored for 2 years:						
	(a) in bulk in lidless containers	40.27	3.50	0.914	2.18	193.5	103.9
	(b) in gunny bags	39.06	3.67	0.915	2.87	191.7	104.4

It will be seen from Table I that the figures obtained for the seeds stored for two years, whether in bulk or in bags, do not show any appreciable differences either between themselves or from the initial values obtained in respect of the fresh, original seed-samples. Slight variations exhibited by the figures are of no practical import because they are of such a nature as fall within the limits of experimental and sampling errors The obvious conclusion, therefore, is that if dry, fully ripe, sound and fresh rape-seed is stored, whether in bulk or in bags, in well-ventilated stores, impervious to rain or seepage water, the seed does not undergo any deterioration at all for a period of two years at least. This good keeping quality of the rape-seed is attributed generally to the fact that the oil contained in it acts as a preservative. The oil probably also acts as a deterrent to insects as no insect pests are so far known to seriously attack rape-seed specifically in stores. Rats, black ants and white-ants damage the stored rape seed if they can have access to it, but their depredations can be entirely checked if the seed is stored in godowns having cemented floors, cement-plastered walls and flat ceilings, and,

if possible, having on all the four external boundaries, with no bridges across it, a small, narrow, cemented drain in which water may be kept standing continuously to prevent incursion of black ants to stores from outside.

Effect of storage on oil

Review of past work. As already stated no work has been done in India on changes that take place in rape-oil on storage. Some attention has been given in other countries to evaluate changes occurring on the oxidation of drying oils, but even there non-drying or semi-drying oils (between which two classes of oils, the rape-oil occupies an intermediate position) do not seem to have been studied from this standpoint and very little published literature exists on the subject. The only notable contribution in this direction is that of Gripper [1899] who has given characteristics of old rape-oils kept in corked bottles in full daylight from 4 to 10 years. Air had access to the oils under experiment. By working on these oils which had absorbed oxygen gradually, he adduced evidence in support of the findings of Thomson and Ballantyne [1892] on blown rape-oil to the effect that as the specific gravity and potash absorbing power increased there was a proportionate decrease in iodine absorption, and that the change was not attended by the development of any considerable amount of fatty acids. Later Procter and Holmes [1905] showed that as the time of blowing rape-oil with air at 100°C. increased, the specific gravity and refractive index of the oil increased but the iodine value decreased correspondingly.

Methods and material. As the oils obtained from seeds of the aforesaid four species of plants grouped commercially under the term rape-seed do not show much variation among themselves, only oils of *toria* and brown-seeded *sarson* were employed for experimental purposes. Samples of these oils, expressed from the seeds of these two crops obtained from a number of Agricultural Farms in the Punjab, were put in clean glass-stoppered (but not airtight) bottles which were placed in a cupboard to shut out the light. The samples were stored for a period of six years and at yearly intervals small quantities were withdrawn from the bottles and analysed for some of their physical and chemical constants. At the time of withdrawing samples no precautions were taken to exclude air which consequently had free access to the oil during this operation.

Results and conclusions. The results obtained are given in Table **II**, wherein values obtained for fresh oil are also added for comparison.

Table II

Effect of storage on rape-oil

Kind of oil	Age of oil	Specific gravity at 15.5°C.	Acid value	Saponification value	Iodine value	Remarks
Toria oil	Fresh	0.915	2.62	174.1	102.9	Average of 8 samples
	One year old	0.915	4.31	175.3	103.4	,,
	2 years old	0.916	5.09	177.8	102.3	,,
	3 years old	0.916	5.96	174.2	99.7	,,
	4 years old	0.919	7.43	179.7	98.3	Average of 7 samples
	5 years old	0.923	10.01	183.9	99.9	Average of 6 samples
	6 years old	0.925	13.60	178.9	100.2	,,
Brown *sarson* oil	Fresh	0.915	0.65	176.4	102.9	Average of 12 samples
	One year old	0.914	1.60	176.4	102.9	,,
	2 years old	0.915	2.20	178.0	102.1	,,
	3 years old	0.915	3.39	181.7	101.5	,,
	4 years old	0.917	3.96	177.7	100.5	,,
	5 years old	0.924	4.91	181.6	97.9	,,
	6 years old	0.924	8.62	179.5	99.2	,,

It will be seen from the figures given in Table II that :

(i) The Acid value has shown a progressive and marked increase with the passage of time, it having increased from 2.62 and 0.65 in fresh *toria* and *sarson* oils, respectively, to 13.60 and 8.62 in six years old oils.

(ii) There is a general tendency for the specific gravity to increase with the age of the oil, the increase being particularly discernible after the oils had become more than three years old.

(iii) As compared to fresh oil, the iodine value is lower in all samples more than one year old.

(iv) Though the saponification value has exhibited no regular trend, yet, as in all cases (excepting one in which it is equal to that of fresh oil) it is higher in old samples than in the fresh ones, it may be inferred that there is a tendency for the saponification value to increase in old samples.

The above findings are in line with those of Gripper (1899) who found that with an advance in the age of rape-oil (to which air had access) specific gravity, saponification value and soluble free fatty acids increased, while iodine value decreased.

Athawale, Duke and Mathur [1938] after examining a large number of samples from all over India suggested the following range of physical and chemical constants, among others, as characteristic of pure commercial mustard (rape) oil produced in India :

1. The specific gravity of the oil at 15.5°C./15.5°C. should not be lower than 0.912 nor higher than 0.916.
2. The saponification value of the oil should not be less than 169 nor higher than 178.
3. The iodine value of the oil should not be less than 96 nor higher than 108.
4. The acid value of the oil should not exceed 5.

Applying these criteria to the figures given in Table II, it will be seen that so far as the iodine value is concerned, the figures given both for *toria* and brown *sarson* oils fall within the range suggested above; that as regards specific gravity, both the oils come up to commercial standard up to three years of storage ; that in the matter of saponification value, *toria* oil for three years and brown *sarson* oil for two years of storage did not transgress the limits suggested above ; and that in respect of the acid value, *toria* oil for nearly two years and brown *sarson* oil for five years of storage remained within the maximum limit suggested.

Considered from the standpoint of above limits, it may be taken that, under the conditions of the experiment, both *toria* and brown *sarson* oils would pass muster as pure commercial rape-oil up to two years of storage. As already stated some air had access to these oils in this experiment, but if the air had been entirely excluded it is possible that the oils would have retained their status as pure commercial rape-oils for a considerably longer period as was found to be the case by Gripper in his studies on rape-oil to which air had no access.

Summary

The results reported in this paper represent the first attempt made in India to assess experimentally the changes that rape-seed and rape-oil undergo during storage.

Seeds of *toria* (*Brassica campestris* L., var. *toria* D. and F.), brown-seeded *sarson* *B. campestris* L., var. *dichotoma* Watt.), yellow-seeded *sarson* (*B. trilocularis* H. f. and T.) and *raya* (*B. juncea* H. f. and T.) are designated commercially as rape-seed. If dry, fully ripe, sound and fresh seeds of these plants are stored, whether in bulk or in bags, in well-ventilated stores, impervious to rain or seepage water, the seeds for a period of two years at least undergo no deterioration in quality as judged by their oil and nitrogen contents and from the determinations made in respect of the specific gravity, acid value, saponification value and iodine value of the oils expressed from them.

Toria and brown *sarson* oils when stored for a period of six years under conditions in which air had some access to them, did not undergo, for a period of two years, a change in their physical and chemical constants to such an extent as would have placed them beyond the pale of pure commercial rape-oil.

With an increase in the age of the oils, the acid value increases markedly, and the specific gravity and saponification value exhibit a tendency to increase, while the iodine value shows a tendency to decrease.

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A STUDY OF THE CHEMICAL COMPOSITION AND YIELD OF BERSEEM (*TRIFOLIUM ALEXANDRINUM*) AS INFLUENCED BY THE INTERVALS BETWEEN CUTTINGS

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BERSEEM is one of the most favourite fodder with owners of live-stock because it yields several cuttings of highly nutritious fodder for about six months in a year and is available in late November and continues right up to the wheat harvesting season when other green fodders are not usually available in the Punjab. In addition, it enriches the soil owing to its nitrogen fixing power.

Increasing the yield of such a useful fodder is a matter of great economic importance. The yield depends not only on the supply of water and the fertility of soil, but also upon the frequency and intervals between cuttings. Many workers, notably Paterson [1933-35], Wilsie and Takahashi [1937], and Lander [1942], report that the frequency of cutting affects both the quality and quantity of fodders and grasses. No systematic work has so far been done on berseem on these lines. An experiment was, therefore, carried out with a view to studying the relationship between the intervals of cuttings and the yield and quality of berseem, the results of which are reported in this paper.

EXPERIMENTAL

A piece of land measuring about one and a half acres was selected at the Lyallpur Agricultural Farm. Four treatments, viz. 15, 30, 45, 60 days' intervals between the successive cuttings were tried on the randomized block system with six replicates.

The relevant details of the experiment and the Agricultural operations carried out are given below :

A. Interval between successive cuttings 15 days.
B. ,, ,, ,, ,, 30 ,,
C. ,, ,, ,, ,, 45 ,,
D. ,, ,, ,, ,, 60 ,,

Size of each plot 106./25 ft. $\times$ 20.49 ft.=1/20 acre.

Preliminary cultivation

One ploughing with a furrow turning plough followed by three ploughings with the *desi* plough and subsequent tillage with horse-hoe and *sohaga* were carried out.

Date of sowing	30-9-1941
Seed rate	12 seers per acre
Previous crop	Berseem
No. of irrigations	12

Cuttings were obtained from individual plots on dates reckoned from 9.12.1941, this being the date of first common cutting in this experiment. Fresh weight of green herbage removed was recorded each time. Representative samples of fodder obtained from all the plots were chopped immediately and dried in an air-oven and ash, protein, calcium, phosphorus and potassium were estimated in each of the samples.

Methods of analysis followed were those recommended by the Associations of Official Agricultural Chemists [1940].

Results

The average chemical composition of the fodder obtained from different cutting treatments is given in Table I. These data have been arrived at by dividing total quantity of individual constituents obtained per plot throughout the growing period after 9.12.1941 by the dry matter in that plot and expressing them as percentage of dry matter.

TABLE I

Average chemical composition of berseem with different intervals of cuttings

Serial No.	Plot No.	Percentage of dry matter	Percentage of oven-dried material				
			Ash	Protein	CaO	P_2O_5	K_2O
			15 days' interval (average of 9 cuttings)				
1	4	17.3	20.3	20.8	2.47	0.84	3.68
2	6	16.6	18.6	21.9	2.56	0.81	3.70
3	10	17.5	18.4	22.5	2.48	0.88	3.98
4	13	15.9	17.8	22.1	2.41	1.02	4.07
5	18	16.1	16.7	22.1	2.42	0.83	3.89
6	21	17.5	20.9	20 9	2.41	0.80	3.71
Average		16.8	18.8	21.7	2.46	0.8	3 84
			30 days' interval (average of 5 cuttings)				
7	2	12.6	15.8	20.9	2.55	0.76	4.93
8	8	13 6	17.0	21.3	2.62	0.69	4.38
9	11	15.9	15.3	20.5	2.53	0.69	4.47
10	16	13.9	15.1	20.8	2.52	0.72	4 31
11	20	12.2	15.4	21.8	2.61	.67	4.27
12	22	13.2	14.7	20.4	2.56	0.68	
Average		13.6	15.6	21.0	2.56	0.70	4.45
			45 days' interval (average of 4 cuttings)				
13	3	18 0	11.4	15.6	2.53	0.47	3.11
14	5	19.0	12.3	14.9	2.56	0.43	3.20
15	9	20.0	11.6	14.1	2.46	0.40	3.09
16	14	20.5	13.0	15.7	2.60	0.50	3.34
17	17	19.2	11.8	15.7	2.57	0.45	3.40
18	24	19.0	12.9	15.9	2.47	0.44	3.76
Average		19.3	12.3	15.3	2.53	0.45	3.32

TABLE I

Average chemical composition of berseem with different intervals of cuttings—concld.

Serial No.	Plot No.	Percentage of dry matter	Percentage of oven-dried material				
			Ash	Protein	CaO	P_2O_5	K_2O
			60 days' interval (average of 3 cuttings)				
19	1	18.0	14.1	14.3	2.52	0.45	3.45
20	7	22.3	11.3	15.3	2.62	0.42	2.66
21	12	21.3	11.9	13.6	2.52	0.37	3.14
22	15	20.5	13.4	14.0	2.38	0.45	2.92
23	19	20.9	11.7	13.5	2.33	0.42	3.23
24	23	21.4	11.1	14.9	2.53	0.44	3.20
Average		20.7	12.2	14.3	2.48	0.43	3.10
Critical difference		1.2	0.7	0.8	0.08	0.07	0.10

The layout of the experiment admitted of statistical interpretation of the results and average figures along with the critical difference are also given in the same table.

The figures showing the yield per acre of green fodder and of its various constituents obtained after 9.12.1941 are given in Table II. The data were analysed statistically but as the variations in treatments between A and B were found to be far less than those of C and D, the three degrees of freedom for treatments were further split up into three parts, one for comparison between X (A and B) and Y (C and D), another for comparison between A and B are with X and the third for comparison between C and D are within Y. Observed values of '**F**' are given in this table.

TABLE II

Yield of berseem and its constituents in maunds per acre when cut at different intervals of time

Serial No.	Plot No.	Green herbage	Dry matter	Ash	Protein	CaO	P_2O_5	K_2O
			15 days' interval (total of 9 cuttings)					
1	4	103	17.8	3.62	3.70	0.44	0.150	0.66
2	6	105	17.5	3.26	3.84	0.45	0.142	0.65
3	10	81	14.1	2.60	3.18	0.35	0.124	0.56
4	13	98	15.6	2.78	3.46	0.38	0.160	0.64
5	18	87	14.0	2.34	3.10	0.34	0.116	0.54
6	21	76	13.2	2.76	2.76	0.32	0.106	0.49
Average		92	15.4	2.89	3.34	0.38	0.133	0.59
			30 days' interval (total of 5 cuttings)					
7	2	228	28.7	4.54	6.00	0.73	0.218	1.42
8	8	197	26.9	4.56	5.72	0.70	0.184	1.18
9	11	145	23.1	3.54	4.72	0.58	0.160	1.03
10	16	168	23.4	3.54	4.86	0.59	0.168	1.02
11	20	189	25.0	3.84	5.44	0.65	0.168	1.08
12	22	154	20.4	3.00	4.16	0.52	0.138	0.87
Average		180	24.6	3.84	5.15	0.63	0.173	1.10

TABLE II

Yield of berseem and its constituents in maunds per acre when cut at different intervals of time—concld.

Serial No.	Plot No.	Green herbage	Dry matter	Ash	Protein	CaO	P_2O_5	K_2O
			45 days' interval (total of 4 cuttings)					
13	3	629	113.3	12.94	17.68	2.86	0.526	3.53
14	5	597	113.1	13.88	17.68	2.89	0.488	3.62
15	9	589	117.7	13.60	16.62	2.90	0.474	3.63
16	14	644	131.7	17.18	20.66	3.43	0 664	4.39
17	17	577	111.0	13.08	17.38	2.85	0.500	3.77
18	24	496	94.2	12.18	15.02	2.33	0.412	3.54
Average		589	113.3	13.81	17.51	2.88	0.511	3.74
			60 days' interval (total of 3 cuttings)					
19	1	664	119.4	16.84	17.42	3.01	0.542	4.12
20	7	602	134.2	15.14	20.48	3 52	0.566	3.54
21	12	512	109.0	13.00	14.82	2.57	0.408	3.43
22	15	567	115.9	15.54	16.24	2.67	0.524	3.38
23	19	485	101.3	11.84	13.66	2 36	0.428	3.27
24	23	497	106.5	11.28	15.04	2.56	0.446	3.24
Average		555	114.4	13.94	16.23	2.83	0.484	3.50
Observed value of 'F'	Between 'X' and 'Y' 729 Within 'X' ......91 Within 'Y'........ 2.5		623 212 0.02	281 31 0.7	369 99 0.1	375 95 0.1	255 25 0.7	3090 52 1.3

DISCUSSION OF RESULTS

Effect of cutting treatments on chemical composition

From the data in Table I, it will be observed that with regard to their variations with different cutting treatments, the chemical constituents can be divided into two groups. The constituents of one group comprising ash, phosphorus and protein vary in a decreasing proportion with increase in the interval of cutting. The remarkable fact about the decrease is that it takes place in two distinct steps. It is significantly high between the 15 day and 30 day intervals, most marked between the 30 day and 45 day intervals, while it is hardly appreciable between 45 and 60 day interval. The other group contains calcium, potossium and dry matter. There is very little change in the calcium contents of the fodder due to different intervals between cuttings. Dry matter contents increase with increase of intervals except a significant fall with 30 day interval. Potash contents, however, decrease with age except during 30 day interval when it shows a significant increase.

Effect of cutting treatments on yield

From Table II which gives the yield data and their statistical interpretation, it will be seen that there is an increase in yield with an increase in the interval between successive cuttings from 15 to 45 days. The increase, however, is not uniform, for instance the increase in yield obtained from cutting at 30 day interval is very small compared with the increase resulting from cutting at 45 day interval. But there is no further increase in yield when the interval is increased from 45 to 60 days. This comparison can best be made by looking at the values of 'F'. The inference is that the active period of growth for berseem is between 30 and 45 days after cutting; the rate of growth before and after this period being much less.

The above results can briefly be summarized as below :

(i) With the shorter intervals between cuttings (15 or 30 days) the quality of the fodder is good, but the yield is very low.

(ii) Cuttings at intervals of 45 days give the highest total yield of fodder. The quality of fodder is inferior but the increase in yield compensates for loss in quality.

(iii) Cuttings at longer intervals (60 days) result in deterioration in quality with no advantage in quantity.

Effect of frequency of the yield of successive cuttings

In Table III are given the average yield of green herbage and of dry matter, per plot, of successive cuttings obtained throughout the life cycle of berseem under different cutting treatments.

TABLE III

Average yield of green herbage and dry matter in maunds per plot obtained in individual cuttings

No. of cutting	15 days' intervals		30 days' intervals		45 days' intervals		60 days' intervals	
	Green herbage	Dry matter	Green herbage	Dry matter	Green herbage	Dry matter	Green herbage	Dry matter
1	1.44	0.225	3.68	0.480	7.32	0.995	9.55	1.398
2	0.39	0.059	2.70	0.338	10.82	1.339	17.04	3.613
3	0.86	0.128	1.78	0.228	10.81	3.186	1.14	0.709
4	0.60	0.091	0.68	0.136	0.47	0.188		
5	0.30	0.051	0.12	0.047				
6	0.35	0.062						
7	0.35	0.062						
8	0.23	0.071						
9	0.05	0.020						

It will be observed that successive cuttings obtained at the intervals of 15 and 30 days show a significant fall in the yield. In the case of 45 days and 60 days, no such deterioration was noticed. In this case the low yield of the last cutting was due to the effect of hot and dry weather in May. This phenomenon has also been reported by Paterson [1933] and Wilsie *et al.* [1940] in the case of Napier grass (***Pennisetum Purpureum***) who state that greater frequency of cutting affects the vitality of the grass, retards the growth of the root system which results in a less virile stool. It appears that all these factors are also operative in the case of berseem. The low yields of berseem cut at shorter intervals can thus be explained as being due to the fact that its active period of growth lies between 30 and 45 days and more frequent cuttings affect the vigour of the plants adversely resulting in lower yields of subsequent cuttings.

Leaf/stem ratio

It is well-known that most of the plant food is stored in the leaves and the stems are comparatively poor in their nutritive value. By actual feeding trials with alfalfa leaves and stems, Sotola [1933] found that the percentage of digestible protein and total digestible nutrients in the case of stems were 4.17 and 41 55 respectively, while in the case of leaves they were 14.87 and 57.82. Thus besides the actual chemical analysis, the leaf/stem ratio should indicate the quality of the fodder. During the course of this investigation, leaves and stems of berseem under different cuttings were separated and analysed for various constituents.

The leaf/stem ratio and the results of chemical analysis of leaves and stems are given in Table IV.

TABLE IV

Chemical analysis of leaves and stems

Treatment	Leaf/stem ratio		Percentage of dry matter	Percentage on dry matter			
				Protein	CaO	P_2O_5	K_2O
15 days	2.17	Leaves Stems	20.6 10.4	26.4 12.6	2.78 2.05	1.04 0.58	3.64 4.52
30 days	1.08	Leaves Stems	21.6 8.6	26.8 12.0	2.96 2.20	0.94 0.46	3.58 5.16
45 days	0.55	Leaves Stems	23.1 16.8	20.3 10.8	3.28 2.09	0.64 0.36	3.04 3.54
60 days	0.48	Leaves Stems	25.6 17.8	18.2 10.0	3.42 2.00	0.56 0.34	2.96 3.26

It will be seen that longer intervals between cuttings decrease the ratio of leaves to stalks. Chemical analysis shows that leaves are richer in dry matter, protein, calcium and phosphorus than stalks while the latter were found to be richer in potash in case of all the cutting treatments. Protein and phosphorus contents of leaves and stems go on decreasing with age, but dry matter and calcium contents of leaves show a marked rise with age.

From the point of view of quality, it is, therefore, clear that the crop is more leafy if cut at shorter intervals and young leaves are richer in nutritive elements than the old ones; these are factors which contribute to the superior quality of young growth.

SUMMARY

Results of an investigation into the effect of different intervals between the cuttings on the chemical composition and yield of berseem are reported.

The ash, protein and phosphorus contents of the fodder are found to decrease with increase in the cutting intervals but the fall between 15 and 30 days' intervals is smaller as compared to that with 45 days; further fall from 45 to 60 days is negligible.

The moisture, calcium and potash contents show a marked rise from 15 to 30 days' intervals but they decrease when the interval is increased to 45 or 60 days.

From the yield point of view 45 days' intervals have been found to be most suitable.

The active period of growth of berseem has been found to lie between 30 and 45 days when most of the dry matter is formed.

A greater frequency in cutting adversely effects the growth and yield of successive cuttings.

Shorter intervals produce fodder with narrow leaf/stalk ratio and the chemical analysis of leaves and stalks shows that the leaves are richer in dry matter, protein, calcium and phosphorus than the stems. The younger leaves are richer in phosphorus, potash and protein than the older ones which, on the other hand, are richer in calcium.

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EFFECT OF MANURING ON THE *SCLEROTIAL* WILT OF *PAN* (*PIPER BETLE* L.)

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SEVERAL workers have advocated the use of organic and inorganic manures for the control of diseases caused by soil fungi. King and Loomis [1926] reported that heavy applications of manure or other organic materials consistently reduced the number of cotton plants dying from *Phymatotrichum* root rot. Streets [1934] reported experiments in which *Phymatotrichum* root rot on deciduous fruit and nut trees was controlled with anhydrous ammonia or ammonium sulphate. In a later publication he [Streets, 1937] recommended either ammonium sulphate or ammonium phosphate for this disease on a number of perennial crops. Jordan and others [1934] furnished further evidence of the effect of fertilizer treatments in reducing the loss of cotton from this fungus. Sardina and Landaluce [1934] claim that *Armillaria* root rot of the vine can be controlled only by preventive measures which in addition to extirpation, deep cultivation and drainage of the holes should include replacing of stable manure with well-balanced fertilizers. Walker and Musbach [1939] have obtained marked control of *Aphanomyces* root rot of peas under green house conditions with one application of 4-16-4 fertilizer at the rate of 500 lb. per acre. More recently Smith and Walker [1941] have produced evidence that the nitrogen fraction is more active in reducing of pea root rot than either the phosphorus or potash content when 2-12-6 fertilizer is used. In New Jersey, root rot of peas was reduced by heavy applications of hydrated lime (4000 lb. per acre) but lesser amounts had no inhibitory effect [Haenseler, 1927] and elsewhere, incidence of the rot was delayed and injurious effects on the host greatly reduced by use of 1000-2000 lb. of complete fertilizer per acre [Haenseler, 1931]. Greenhouse tests indicated that nitrate of soda, sulphate of ammonia and muriate of potash were more effective than superphosphate. Reinking [1942] in New York states that in favourable growing seasons, profitable yields of peas were obtained where soils were sufficiently fertilized (600 lb. per acre of a 5-20-5 or 10-20-10 fertilizer) inspite of the pathogenes in the soil. From Louisiana, Le Bean [1938] reports that nitrogenous fertilizers increased *Pythium* root rot of sugarcane, while high phosphate treatment reduced it. The same relationship of nitrate to *Pythium* root rot was also reported from Coimbatore by Ramakrishnan [1941] and from the United States of America by Rands and Dopp [1938]. The author [Chowdhury 1944, 1 & 2] has in his recent experiments found that oilcake and the different combinations of fertilizers have practically no influence on the incidence of *Phytophthora* foot rot and *Rhizoctonia* root rot diseases of *pan*.

Early results with *Sclerotium rolfsii* Sacc. were not encouraging for this line of attack. Edgerton and Tims [1936] reporting trials with 26 fertilizer combinations during two seasons in Louisiana found no clear cut differences between the various treatments. But Leach [1941] reported that the root rot of sugar beet due to *S. rolfsii* can be much reduced by the application of commercial fertilizers containing 100 lb. nitrogen per acre. More recently Leach and Davy [1942] reported consistent reduction in rot of sugar beets caused by *S. rolfsii* by the application of nitrogenous fertilizers. They found that on an average of all trials 50 lb of nitrogen per acre reduced infection by some 28 per cent, 100 lb. by 54 per cent and 200 lb. by 65 per cent. Encouraged by these results the author conducted certain field experiments to determine the possible application of similar methods for controlling *S. rolfsii* on *pan* under prevailing conditions. The results of these experiments are recorded in this paper.

Materials and methods

A piece of land where all the plants died of the disease was selected for the purpose. Examination showed that the field was with uniform infestation of *S. rolfsii*. An additional dose of infective material, however, was added to the soil by incorporating cultures of the fungus containing abundant sclerotia and mycelia into the soil.

The entire piece of land was then divided into 78 plots. Each plot was 15 ft. x 6 ft. There were 10 rows in each plot and 10 healthy *pan* setts were planted in each row. Planting was done in October, 1942.

The first manuring was done during the early part of April, 1943, and the subsequent manurings during the months of May, June, July, August, September and October, 1943.

During the year 1944, manuring was commenced in May and finished in October. Six applications were made, one application in each of the months May, June, July, August, September and October.

In every case the manuring was done on the same day and at the same time. The method of application was also the same. The oilcake was ground very fine, then spread along the ridges and afterwards covered with a thin layer of fine earth. The fertilizers, on the other hand, were mixed with equal quantities of fine earth, thoroughly mixed together and then applied along the ridges just like oilcake and then covered with a thin layer of soil.

The treatments were randomized and each treatment had six replications. The treatments were as follows:—

A. *Control.* No manure of any kind was applied.
B. *Mustard oilcake.* This was applied at the rate of 984 lb. per acre per year.
C. *Mustard oilcake.* This was applied at the rate of 1968 lb. per acre per year.
D. *Mustard oilcake.* This was applied at the rate of 3936 lb. per acre per year.
E. *Ammonium sulphate.* This was applied at the rate of 245 lb. per acre per year.
F. *Ammonium sulphate.* This was applied at the rate of 490 lb. per acre per year.
G. *Ammonium sulphate.* This was applied at the rate of 980 lb. per acre per year.
H. *Sodium nitrate.* This was applied at the rate of 320 lb. per acre per year.
I. *Sodium nitrate.* This was applied at the rate of 640 lb. per acre per year.
J. *Sodium nitrate.* This was applied at the rate of 1280 lb. per acre per year.
K. *Ammonium phosphate.* This was applied at the rate of 312 lb. per acre per year.
L. *Ammonium phosphate.* This was applied at the rate of 624 lb. per acre per year.
M. *Ammonium phosphate.* This was applied at the rate of 1248 lb. per acre per year.

Experimental results

The plots were kept under careful observation and deaths as they occurred were noted. The results obtained are recorded in Table I. The yield of leaves was also ascertained and is recorded in Table I. The dead plants were collected and examined; it was found that in all cases the deaths were due to the attack of the parasite *S. rolfsii*.

TABLE I

Effect of manuring on the sclerotial *wilt of* pan

Treatments	Fertilizer applied per acre in lb.	Nitrogen applied per acre in lb.	Average percentage of deaths		Average yield of leaves	
			1943	1944	1943	1944
Control ...	......	......	27.43	31.90	1752	1204
Mustard oilcake ...	984	50	9.19	7.36	3297	4957
Ammonium sulphate ...	245	50	9.23	7.20	3256	4962
Sodium nitrate ...	320	50	9.16	7.78	3285	4965
Ammonium phosphate ...	312	50	9.37	7.65	3292	4897
Mustard oilcake ...	1968	100	4.62	3.87	4980	6787
Ammonium sulphate ...	490	100	4 50	3.80	5021	6801
Sodium nitrate ...	640	100	4.36	3.72	4992	6792
Ammonium phosphate ...	624	100	4.45	3.85	5101	6800
Mustard oilcake ...	3936	200	2.65	2.01	7216	9456
Ammonium sulphate ...	980	200	2.30	1.87	7234	9621
Sodium nitrate ...	1280	200	2.51	1.90	7197	9572
Ammonium phosphate ...	1248	200	2.25	2.09	7209	9564

It will be observed from the data presented in Table I that the deaths were considerably less in the manured than in the control plots and the extent of death from the attack of the parasite was in proportion to the amount of nitrogen applied; the kind of the manure applied exerted little influence. Thus it will be seen that on an average the percentage of mortality in the plots receiving 50 lb., 100 lb. and 200 lb. of nitrogen per acre a year was 9.24, 3.48 and 2.42 respectively during the year 1943 and 7.49, 3.81 and 1.96 respectively during the year 1944. The different manures, oilcake, ammonium sulphate, sodium nitrate and ammonium phosphate were equally effctive in reducing the wilt. It will also be found that the yields of the leaves were also appreciably increased by these treatments. This was because of the lesser number of deaths and because of the stimulation of growth produced by the manures.

As to the general growth of the plants due to manuring it was found that the effects of the artificial fertilizers were earlier visible on the plants than oilcake, but in the long run no difference could be noticed between the plants given different manurial treatments; the height of the plants, the size and colour of the leaves and the general vigour of the plants were indistinguishable.

The plants in the control plots, on the other hand, were sickly, pale and stunted and the leaves much smaller in size and lesser in number.

SUMMARY

Applications of manures in field plots have consistently reduced the percentage of death of *pan Piper betle*) plants due to the attack of *S. rolfsii*. Mustard oilcake, ammonium sulphate, sodium nitrate and ammonium phosphate proved equally effective and it was

found that the mortality from the attack of the parasite was in proportion to the amount of nitrogen applied, and the form of ntrogen applied exerted little influence. Yields were increased by these treatments both because of the lesser number of mortality and because of the stimulation of growth produced by the manures.

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EFFECT OF HYDROGEN-ION CONCENTRATION ON THE GROWTH AND PARASITISM OF *SCLEROTIUM ROLFSII* SACC.

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(With one text-figure)

Quite a large number of investigators have demonstrated that hydrogen-ion concentration influences the growth and parasitism of certain fungi and that some of the soil-borne diseases of plants could be wholly or partially controlled by altering the hydrogen-ion concentration of the soil. Garrett [1944] has recently furnished a tabulated list of the diseases that are favoured by acid and alkaline soils. Chupp [1928] and Wellman [1930] reported that the club-root disease of crucifers is favoured by acid soils and can be controlled by making the soil alkaline by the addition of lime. Doran [1927, 1928, 1929 and 1931] and Morgan and Anderson [1927] reported the reduction of *Thielaviopsis* black root rot of tobacco and *Phymatotrichum* cotton root rot by increasing soil acidity. Buchholts [1938] found that hydrogen-ion concentration below 6.5 favours root rot of sugar beets. Flor [1930] found that *Pythium* sp. responsible for root rot of sugarcane in Louisiana was capable of growing well from *p*H 5.6 to 9.2 and most of the cane soils were in the neighbourhood of the neutral mark. Marchel [1929] in Belgium reported that though black rot is present in acid soils it is rarely noticed when soil has

a reaction of *p*H 7 or greater. On the other hand, Grossheroy [1931] reported that the heaviest damage from *Phoma* root rot occurred recently in very alkaline and neutral clay soils whereas the epidemic of 1926 took place under acid soil conditions.

Sclerotium rolfsii Sacc. is a soil inhabiting parasite and is known to cause serious damage to *pan* (*Piper betle* L.) in certain parts of Sylhet [Chowdhury, 1945]. A study was therefore made to determine how far the growth and parasitism of this organism are influenced by hydrogen-ion concentrations and whether it is possible to minimize or completely control its ravages by changing soil reactions. The results of this study are reported in this paper.

Mycelial growth

The range and optimum hydrogen-ion concentration for the growth of the organism were determined. Modified Richard's solution of Karrer and Web [1920] was used; 2.5 per cent agar was added. Petri dishes of equal sizes were used and an equal amount of the medium poured in each. The petri dishes were inoculated in triplicate and the linear rate of growth measured from day to day. The rate of growth noticed after five days is presented in Fig. 1.

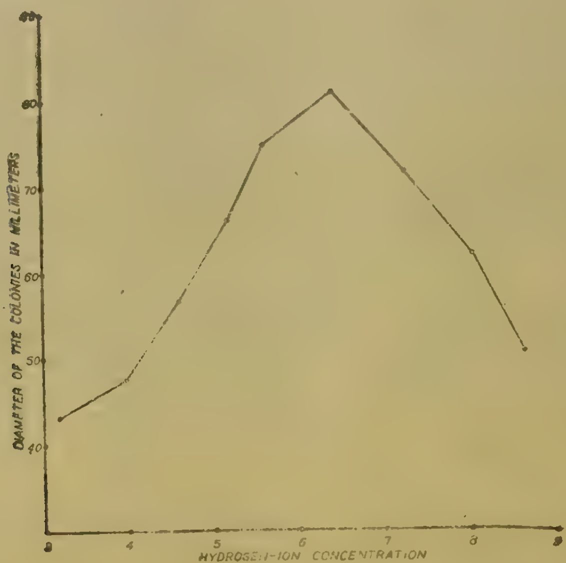

FIG. 1. Growth of *Sclerotium rolfsii* at different hydrogen-ion concentrations

It will be evident from the data presented in Fig. 1 that the fungus has a wide range of tolerance between *p*H 3.2 to 8.6. The optimum, however, lies at *p*H 6.4.

Formation of sclerotia

The formation of sclerotia at different hydrogen-ion concentrations was also studied. Beef-extract agar and Richard's solution agar were adjusted to different *p*H values and the fungus grown on them. The observations were made for 15 days; the results are recorded in Table I.

TABLE I

Effect of hydrogen-ion concentration on sclerotial formation

*p*H	Sclerotial formation		*p*H	Sclerotial formation	
	Beef-extract agar	Richard's agar		Beef-extract agar	Richard's agar
3.5	+	+	6.4	+++	+++
4.0	++	++	7.0	++	++
4.6	++	++	8.0	++	++
5.0	++	++	8.6	+	+

From the data presented in Table I it will be seen that sclerotial formation takes place over a wide range of hydrogen-ion concentration, 3.5 to 8.6 and that the optimum lies at *p*H 6.4.

MORTALITY AT DIFFERENT HYDROGEN-ION CONCENTRATIONS UNDER FIELD CONDITIONS

The hydrogen ion concentrations of a large number of soil samples obtained from healthy and affected fields, collected from the different localities, were determined colorimetrically and were found to vary from 4.2 to 6.3, a range over which *S. rolfsii*, the fungus causing the sclerotial wilt of *pan*, also shows good growth. No appreciable differences in the *p*H values of the soils obtained from healthy and affected fields have, however, been noticed. All the same, an attempt was made to test the effect of changing soil reaction in an infected plot on the incidence of the disease. A piece of land where almost all the plants died of the disease and the fungus was found present in abundance was selected. The *p*H of the soil was determined and found to be 6. The reaction was changed by the addition of sulphur and lime to the soil and equal numbers of healthy cuttings were planted in each of the plots. The different treatments were randomized. Six replications of each treatment were made.

The data of this experiment showing the variations in soil reaction as a result of the addition of lime and sulphur and the average percentage of mortality of plants due to sclerotial wilt are recorded in Table II.

TABLE II

Incidence of the disease in relation to soil reaction

Treatments	Rate per acre in lb.	*p*H	Average percentage of deaths	
			1943	1944
Sulphur	4000	4.1	19.15	16.20
Sulphur	3000	5.4	20.91	17.92
Sulphur	2000	5.7	19.47	19.02
Untreated	......	6.0	19.75	18.78
Lime	2000	6.9	20.42	17.82
Lime	3000	7.6	21.26	16.10
Lime	4000	8.5	19.10	18.52

It will be evident from the data presented in Table II that the hydrogen-ion concentration of the field soil has practically no influence on the incidence of the disease, the average percentage of death being almost the same at all *p*H values. Thus it will appear that there exists no possibility of fighting the disease by altering soil reactions.

SUMMARY

Experiments were conducted to determine the effect of hydrogen-ion concentrations on the growth and parasitism of *S. rolfsii*. It was found that the fungus can grow over a wide range of *p*H and the optimum for growth and sclerotial formation lies at 6.4.

The hydrogen-ion concentration of a large number of soils obtained from healthy and affected fields was determined; no appreciable difference in the *p*H values of these soils could be noticed. The effect of changing soil reaction in an infected plot on the incidence of the disease was studied and it was found that there exists no correlation between the hydrogen-ion concentration of the soil and the incidence of the disease.

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EARLY BLIGHT OF POTATO IN INDIA*

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(Received for publication on 4 February 1946)

THE causal organism of the early blight of potato was first described as a *Macrosporium* by Ellis and Martin [1882] from the dying leaves of potato near Newfield, New Jersey. The first reference to the fungus as a parasite and its association with potato leaf blight was made by Galloway [1891]. For some time there was much disagreement concerning the true cause of the disease. Some believed the *Macrosporium* only a secondary invader and disease primarily of non-parasitic origin, while others considered the fungus a parasite but not the cause of all the trouble. It was not until Jones [1895-96] published the results of further studies that the relation of *Macrosporium* to the various troubles was entirely cleared up. His field and laboratory studies led him to the final conclusion that the

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fungus (*Macrosporium*) was a true parasite and the primary cause of early blight. The fungus was first described as *Macrosporium* by Ellis and Martin [1882], but was assigned to *Alternaria* because of the discovery of Jones [1896] and Sorauer [1891] that the spores were sometimes formed in chains. Rands [1917,] fully described early blight of potato and related plants. Since that time very little has been added to our knowledge of the early blight disease, but during the past decade many valuable data have accumulated bearing upon the control of the trouble by spraying

In India very little work has been done to investigate this disease thoroughly. McAlpine [1911] mentions that it is known in India, where, however, it does not seem to do much damage. Butler [1918] wrote "In India there is no indication at present of its becoming a dangerous pest, though I have on many occasions found it hastening the destruction wrought by *Phytophthora*". Owing to a serious outbreak of potato disease in Nilgiris, McRae, the then Mycologist to the Government of Madras was deputed to make an investigation of the same and advise as to its treatment. The extract of his report was published in the *Agric. J. India* [1911]. McRae mentioned that early blight was reported from the United Provinces in 1903, and for the first time from the Nilgiris in 1910. Ring blight was first reported by Capel [189.] from the Nilgiris. It also occurs in Bombay, Bengal and Mysore. Narasimhan [1935] reported from Mysore that potato fields in a locality where Rickets variety was planted was badly attacked by *Altearnaria* and the growers had sustained considerable loss. Fortunately, *Alternaria solani* is regarded as a weak parasite. It cannot gain a footing and produce much injury, unless the vitality of the plant is lowered. It is usually restricted only to the leaves, occasionally attacking the stem. In India, it is not reported from tubers either in the fields or in storage. In Germany, Belgium and England it can cause extensive damage to the tubers.

It is known that *A. solani* is the causal organism of early blight, but Bulter [1918] wrote that "A form with almost cubical spores (conidia) also occurs in England, but further work is necessary to establish its identity with true *A. solani*". The present author obtained infected plants (leaves) from Ootacamund and Simla, sent by the Imperial Economic Botanist, from Pusa collected by the Imperial Mycologist, and from Naini (Allahabad) sent by Dr Vestal of the Allahabad Agricultural Institute. Several isolations were made from the above material, out of which Simla material only gave typical obclavate, long, beaked spores of *A. solani*, while, from the rest, the author repeatedly got only very small spores without a beak and with longitudinal septa, sporas often being in chains in cultures. This work was undertaken on suggestion of Dr Padwick to ascertain the association of small spored *Alternaria* causing early blight (or leaf-spot) on potato in India.

Symptoms and isolations

(1) *Simla material*. The infected leaves showed typical *Alternaria* spots. They were scattered all over the leaf, roughly circular to elliptic, concentrically zonate, and brown in colour. There were no spores on the spots. The infected leaf, after sterilization, was put in a moist chamber and sterilized bits were transferred aseptically on slants of two and four per cent potato dextrose agar and oatmeal agar, but the fungus did not sporulate either in the moist chamber or on media slants kept at different temperatures. To procure spores the method described by Rands [1917,b] was adopted. Fifteen to twenty-day old cultures in petri dishes were shredded and mycelium severely wounded. The utmost care was taken to avoid contamination. The shredded bits were separated and allowed to dry partially by removing the lid of the petri dish, and exposing to sunlight in a sterilized moist chamber. Within two to three days a few spores were produced. These spores were measured and their morphological characters were recorded. Single spore tubes were prepared on oatmel agar for further studies.

(2) *Ootacamund material*. The same symptoms on leaves as in case of the Simla material, except that the spots were dark-brown to black and the concentric zones in the spots were very indistinct. No spores were formed on the spots. Abundant supply of spores was obtained both in moist chamber and in oatmeal agar slants. Single spore cultures were prepared on oatmeal agar.

(3) *Naini* (*Allahabad*) *material.* Leaves had very irregular black spots without any concentric zones. *Alternaria, Acrothecium* and *Helminthosporium* were found on the surface of the leaf. Infected portions produced very abundant spores both in the moist chambers and oatmeal slants. Single spore cultures were prepared for studies on oatmeal agar.

(4) *Pusa material.* Leaves had very little infection Spots were small, irregular in form, and of light-brown colour. No spores were found on infected patches. Moderate numbers of spores were produced in a moist chamber and on oatmeal agar slants. Single spore cultures were prepared for further studies.

Only the Simla strain, which produced a few spores on wounding, showed typical, long, obclavate, beaked and muriform spores of *A. solani*. The strains isolated from material obtained from Ootacamund, Naini and Pusa, produced small longitudinally septate, short spores, without a beak.

Morphology of the fungus

Cultures of the fungus were prepared on oatmeal agar for use in inoculating the agar slants and perti-dishes of two per cent potato-dextrose agar, oatmeal agar, and tubes of soaked rice which were steamed three times in order to ensure complete sterilization. When the cultures had grown sufficiently, transfers were made of small portions of agar and mycelium to the media in petri-dishes and slants. Duplicate tubes and petri-dishes were prepared. Inoculated tubes and petri-dishes were kept at room temperature, the temperature of the underground room being almost constant, varying from 19 to 20.5 degrees. Morphological characters, change in colour of the media, and measurement of spores were noted after 21 days. Spores were measured and their form and septation recorded from two per cent potato-dextrose and oatmeal agar. The same observations were recorded after 30 days, but no change had occurred since the twenty-first day. If we closely study Table I, it is evident that the aerial mycelium is moderate in amount in Ootacamund and Allahabad strains, while it is nil in Pusa strain on oatmeal agar. It is almost the same in amount on two per cent potato-dextrose, while on steamed rice in strains

Table I

Cultural characters of Alternaria *spp. from potato on different media*

Medium	Fungus	Aerial mycelium		Change in colour of the medium
		Amount	Colour	
Oatmeal agar	Ootacamund	Moderate	Dark olive	No change
,,	Naini	,,	Dark olive gray	,,
,,	Pusa	Nil	...	,,
,,	Simla	Moderate	Olive gray to dark olive gray	Cream buff to chamois
Two per cent potato-dextrose agar	Ootacamund	Moderate	Dark olive	No change
,,	Naini	Good	Dirty-white to pale olive gray	,,
,,	Pusa	Nil	...	,,
,,	Simla	Moderate	Pale brownish drab with scattered small patches of pink	Victoria lake
Steamed rice	Ootacamund	Good	Pale smoke gray	Light grayish vinaceo
,,	Naini	Nil	...	Same as in Ootacamur but very little a change being extrem ly slow
,,	Pusa	Good	Light olive gray	Fawn to army brown
,,	Simla	Very little	Dark olive gray	Cream-buff to chamois

from Ootacamund and Naini the amount is considerable. In the amount of aerial mycelium and general colour, the strains from Ootacamund. Naini and Pusa closely agree. All these three strains produce no change in colour of the media with oatmeal agar and two per cent potato-dextrose agar, but on steamed-rice they form some colour. On steamed-rice, strains from Ootacamund and Pusa show appreciable amounts of colour, but Naini strain is less chromogenic than the former two, and it is slow in developing colour. In short, in amount and colour of aerial mycelium. all the three closely resembled one another and they are entirely non-chromogenic on oatmeal agar and two per cent potato-dextrose agar, and partially chromogenic on steamed-rice. Measurements of the spores, and their septation, recorded in Table II, clearly reveal that all these three strains are morphologically similar.

The Simla strain differs much from those of Ootacamund, Naini and Pusa, being long-sported and highly chromogenic. It shows a moderate to good amount of aerial mycelium on oatmeal and potato-dextrose agar, the mycelium being olive gray on oatmeal agar and potato-dextrose; while on steamed rice, it develops very little olive gray mycelium. It is highly chromogenic on all the three media.

TABLE II

Measurements of the spores and their separation

Strain	Dimensions (excluding beak)	Average dimensions of beak	No. of transverse septa	No. of longitudinal septa	Colour of spores
Ootacamund	25 x 12 (11-52 x 8·19)	Lacking	0—6	0—3	Buffy olive
Naini	23 x 12 (8-41 x 9·15)	Lacking	0—5	0—3	Saccardo's olive
Pusa	24 x 11 (11-45 x 8-15)	Lacking	0—6	0—3	Brownish olive
Simla	140 x 18 (105-194 x 13-22)	42 x 4	4—19	0—4	Dark olive with beak of lighter colour

Average dimensions, septation, colour, etc., are shown in Table II. It is seen that the spores of Ootacamund, Naini and Pusa strains agree in their dimensions, septation, colour and abundance. Spores of the Simla isolation are long, obclavate, olivaceous, very variable in shape, terminating in a very long and bright coloured or partly hyaline septate beak, the latter being frequently branched. Conidia were not observed in chains in Simla strains, but chains of 3 to 6 spores were seen in cultures of Ootacamund, Naini and Pusa strains, on all the three media used for the study.

PATHOGENICITY

Tubers of potatoes from Simla were planted in pots and three plants were inoculated with each strain at the age of two and a half months. Each inoculated plant was placed under a bell jar, and sprayed with sterilized water twice daily for three days. Uninoculated plants were similarly placed under bell jars and sprayed daily to serve as controls.

The following inoculation methods were used :

(1) A drop of sterilized water containing a large number of spores was placed on a leaf, which was partially covered with a small piece of cotton wool soaked in a similar spore suspension. The method was used for all except the Simla strain, which formed too few spores.

(2) Leaves were sprayed with a spore suspension, and kept moist with a fine spray of water for 72 hours. This method was not used for the Simla strain.

(3) Leaves were washed with distilled water. Small punctures were made with a steel needle on the surface of the leaflets and stems. A small piece of potato-dextrose agar with abundant mycelium was placed on the area punctured with the needle. Moist cotton wool was kept for 48 hours on the agar. The plants were sprayed with water for 72 hours.

The method was used only for the Simla strain.

These were intended as preliminary experiments only and the results are, therefore, given briefly as follows:

Ootacamund strain

Method 1.—Out of 20 inoculations made, only one small irregularly shaped discoloured patch was formed. The fungus was reisolated.

Method 2.—Numerous pin-head sized spots appeared, which did not enlarge. From 20 small infected pieces, the fungus was reisolated in four cases.

Naini strain

Method 1.—Results identical with Ootacamund strain.

Method 2.—Symptoms as in Ootacamund strain. From 30 infected pieces, the fungus was reisolated in three cases.

Pusa strain

Method 1.—A number of spots were formed, larger than with the Ootacamund and Naini strains, light brown, irregular in shape. From six infected pieces, the fungus was isolated in one case only.

Method 2.—Failed to take infection.

Simla strain

Method 3.—Numerous large patches formed on the leaves, which increased in size as the leaves withered. Concentric rings were not formed. From ten infected pieces, the fungus was reisolated in six cases.

These tests were conducted in March, when the temperature in Delhi is abnormally high for growing potatoes, and at a time when the disease does not usually appear. The method of inoculation, in the case of the Pusa strain, was different from, and more severe than, that used with the other strains. That the Simla strain is highly pathogenic on injured plants is clear. Infection clearly took place with the other strains, but was much less severe, due possibly to the fact that the plants were not injured, possibly to the high temperatures prevailing.

Discussion

Cooke [1905] described the leaf-curl of potato, due to *M. solani* (Cooke). Afterwards it was discovered by Saccardo that a species had already been named *M. solani*, wherefore, he called the present species *Macrosporium Cookii*, and it became known as a virulent parasite. The measurement and other characters of the small-spored *Alternaria* isolated from Ooty, Naini and Pusa materials do not agree with *M. Cookii* (Saccardo).

Elliot [1911] fully described the taxonomic characters of the genera *Alternaria* and *Macrosporium*. According to him, all obclavate, ovate, cuneate, or elongated pointed spores of the *Macrosporium-Alternaria* type form chains and belong to *Alternaria*. The small-spored strains which occasionally formed chains in culture, and the formation of characteristic *Alternaria* spots on the host, clearly indicate that they all belong to the genus *Alternaria*. Incomplete descriptions, mutations, secondary development of spores, dwarfing of spores in cultures, and facultative parasitism resulting on large host ranges, have created great confusion in the classification of species of *Alternaria*. Elliot [1911] placed the species of

Alternaria in seven main morphological groups, and he stressed the point that echinulation is not a constant character. He showed that generic name *Macrosporium* should be abandoned, because all the species of *Macrosporium* belong to *Alternaria* or *Stemphylium*, having catenulate, sarcinae form, or globose conidia.

Young [1929] collected the literature on *Alternaria* and *Macrosporium* and tabulated the measurements of the spores of *Alternaria* and *Macrosporium* on different host genera of *Solanaceae*. He arranged the species in the table on the basis of minimum spore lengths. The measurements of the small-spored *Alternaria* mentioned in this paper do not agree with his measurements of *Alternaria* spp. on the genus *Solanum*. However, they agree with his measurements of *Alternaria* on the genus *Lycopersicum*, namely 14.60 x 7.20 and 14.56 x 11-14, the dimensions of the strains from Ootacamund, Naini and Pusa being 24 x 12, 23 x 12 and 24 x 11 respectively. This indicates that the small-spored *Alternaria* resembles the one on *Lycopersicum*. It somewhat resembles *A. tomato* Cooke in the amount of sporulation, colour, mode of septation and measurement of spores. A culture of *A. solani* Cooke was obtained from Baarn, but failed to form spores.

It seems possible, but is by no means certain, that the small-spored *Alternaria* isolated from potato leaves from Ootacamund, Naini and Pusa may be *A. tomato* Cooke.

To come to a definite conclusion, it is essential to try again the pathogenicity tests on potato, and also with Ootacamund, Naini and Pusa strains on young tomato plants.

Summary

(1) Isolations were made from diseased patches on potato leaves, obtained from Ootacamund, Naini, Pusa and Simla, suffering from "early blight."

(2) *Alternaria* isolates from Ootacamund, Naini and Pusa closely resemble each other in their form, colour and cultural characters. They are non-chromogenic on oatmeal and two per cent potato dextrose agar, but partially chromogenic on steamed rice. The Simla strain formed a small number of spores which were long, beaked, obclavate and typical *A. solani* spores; cultures of this strain were chromogenic.

(3) Symptoms on the host and pathogenicity tests indicate that Simla strain is highly pathogenic, while Ootacamund, Naini and Pusa strains are weak parasites.

(4) In India "Early blight" of potato is not only due to *A. solani* but it is also due to a small-spored, abundantly to moderately sporing, and partially chromogenic species, possibly *A. tomato* Cooke.

(5) Further pathogenicity tests on potato and tomato plants are suggested.

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A PRELIMINARY NOTE ON THE ESSENTIAL OIL BEARING PLANTS GROWING IN KASHMIR

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Considerable quantities of essential oils are in demand in India for medicinal and cosmetic purposes and most of these are at present imported into India. It has been observed that a large number of essential-oil bearing plants grow in a state of nature in Kashmir and the experimental cultivation of most of the exotics has been successful in the forest nurseries.

A preliminary investigation of these plants was undertaken to ascertain whether the oils obtained from these could be successfully exploited for the above purposes. The percentage yield of the oil from the plant was ascertained and the specific gravity and refractive index of the oils obtained was tested. Detailed investigation of the essential oils obtained from some of these plants is in hand and will be communicated in due course. The plants named below were studied.

Mentha sylvestris (VERN. *Jangli Pudina*)

It is very common in Kashmir growing wild on the sides of water streams and other damp localities. The plant is often used in indigenous medicine as a carminative, antiseptic and stimulant. The dried leaves and flowering tops of the plant were steam-distilled and a pale yellow oil with a minty odour was obtained. The results of analysis of the oil are given in Table I along with those of the Cyprus oil [Gildemeister and Hoffmann, 1922.]

Table I

Results of anaylsis of the oil of Mentha sylvestris

	Local oil	Cyprus oil
Yield of the oil	1.2 per cent	0.9 per cent
Specific gravity	0.985 at 15° C.	0.9852 at 15°C.
Refractive index	1.471 at 20° C.	1.4685 at 20°C.
Ester value	65.8	20.9

Mentha arvensis (VERN. *Pudina*)

The plant is found wild in the Kashmir valley at an altitude of 5,000 to 10,000 ft. and is very common near Gulmarg. It is used locally as a stimulant and carminative. The dried leaves and flowering tops on steam distillation gave a pale brown essential oil, the properties of which are compared in Table II with the properties of Japanese natural and dementholished oil [Parry, 1921].

Table II

Properties of the essential oil of Mentha arvensis

	Local oil	Japanese natural oil	Dementholised oil
Yield of the oil	0.45 per cent	1.07 to 1.6 per cent	1.07 to 1.6 per cent
Specific Gravity	0.9161 at 15° C.	0.90 to 0.912 at 15° C.	0.894 to 0.906 at 15° C.
Refractive index	1.474 at 20° C.	1.4600 to 1.4635 at 20° C.	1.459 to 1.465 at 20°C.

On allowing the oil to stand at 0°C., no crystals of menthol separated.

Mentha piperita

The plant is not indigenous in India. Some rooted suckers of the plants were obtained from the Punjab Agriculture College, Lyallpur, for trial cultivation. The suckers were transplanted successfully in the drug nursery of the Forest Department at Baramulla. The dried flowering tops and leaves of the plant were steam distilled and 0.71 per cent of essential oil was recovered.

In England the yield of the oil from the dry herb varies from 0.5 to 1.0 per cent and in Russia a yield from 1.6 to 1.7 per cent from the dried leaves is the average [Parry 1921].

As the quantity of the sample obtained was small, sufficient oil could not be obtained for studying its properties.

Mentha pulegium (Pennyroyal)

Pennyroyal oil is used in considerable quantities in perfumery and soap making. The plant is not indigenous to Kashmir but has been successfully cultivated at the forest nursery Baramulla. The principal constituent of the pennyroyal oil is a ketone called pulgone. This can be changed to menthone and then to menthol which has a great demand in India. The dried leaves and flowering tops of the plant were steam-distilled and the properties of the oil obtained are compared in Table III with those of the Mediterranean Pennyroyal oil [Gildemeister and Hoffmann, 1922].

TABLE III

The properties of the oil of Mentha pulegium

	Local oil	Mediterranean oil
Yield of the oil	2.3 per cent	—
Specific gravity	0.8925 at 15° C.	0.93 to 0.95 at 15°C.
Refractive index	1.483 at 20°C.	1.483 to 1.486 at 20°C.

Inula racemosa (VERN. *Poshkar*)

It is a moisture loving plant, grows on elevations ascending from 7,000 to 9,000 ft. and is common in Gurez and Gulmarg. The roots are used in indigenous medidines for their expectorant, diaphoretic and emmenagogue properties. They possess a mild aromatic odour and are sometimes used to adulterate ***Sausurea lappa*** (*Kuth*) which brings a higher price in the market. It is collected early in autumn when the seeds mature. On steam-distilling the dry roots gave 0.38 per cent of essential oil which solidified on standing. Further properties, i. e. specific gravity and refractive index, are being studied.

Lavanduta officinalis

Quite a large amount of lavender oil is used in India in perfumery and soap-making and the whole of this is imported from foreign countries.

The seedlings of this plant were imported and experimental cultivation was started at the drug nursery of the Forest Department. The dry flowers were steam-distilled and the results of analysis of the oil obtained recorded. For comparison the properties of the English oil [Gildemeister and Hoffmann, 1922; British Pharmacopoeial Codex, 1934] are also given in Table IV.

TABLE IV

Properties of the oil of Lavendula officinalis

	Local oil	English oil
Yield of the oil	2.4 per cent (of the dry flowers)	0.8 to 1.7 per cent (of the fresh flowers)
Specific gravity	0.9192 at 15°C.	0.882 to 0.90 at 15°C. (foreign oil 0.883 to 0.895 at 15°C.)
Percentage of ester	24.8 per cent	7 to 14 per cent (foreign oil not less than 35 per cent)

Srimmia laureola

This plant is found in abundance as a undergrowth shrub in fir forests at an altitude of 7,000 to 9,000 ft. It is very common in Gulmarg and Pahalgam. The leaves are often used locally as an incense and in small-pox [Kaul, 1928]. The fresh leaves on steam distillation gave a light oil with the properties given in Table V.

TABLE V

Properties of the oil of Skimmia laureola

Yield of the oil	0.49 per cent
Specific gravity	0.8058 at 15° C.
Refractive index	1.4784 at 20°C.

The oil has been found to contain quite a large percentage of linalyl acetate which is the main constituent of the lavender oil. *Skimmia* oil, therefore, stands a good chance of its being employed in perfumery and soap-making in place of lavender oil.

Thymus serphyllum (VERN. *Ban-ajwain*)

The plant grows wild throughout the Kashmir valley and is used in *Unani* and *Ayurvedic* systems for complaints in stomach and liver and as a remedy for toothaches. The whole dried plant on steam-distillation gave a pale yellow oil. In Table VI are given the properties of the local oil along with those of the European oil [Gildemeister and Hoffmann, 1922]

TABLE VI

Properties of the oil of Thymus serphyllum

	Local oil	European oil
Yield of the oil	0.72 per cent	0.15 to 0.6 per cent
Specific gravity	0.9404 at 15° C.	0.890 to 0.92 at 15°C.
Refractive index	1.5110 at 20° C.	

Saussurea lappa (VERN. *Kuth*)

It is a herbaceous plant growing wild in Kashmir forests. It grows in shady moist places especially under birch trees and dwarf willows. The chief places where it grows abundantly in Kashmir are the Kishenganga valley and the higher elevations of the Chenab valley. It is also found in Reasi, Ramban and Udhampur divisions. The roots are collected in autumn months before snowfall. They are mostly used as stimulant, in cough, asthama, fever, dyspepsia and skin diseases. It is locally employed

as a preservative for woollen goods. Large quantities of this are annually exported to China where it is burnt as an incense in Pagodas [Kaul, 1928].

The dry roots were steam-distilled and a pale brown oil with characteristics as shown in Table VII is obtained.

TABLE VII

Characteristics of the oil of Sausurea lappa

Yield of the oil	1.22 per cent
Specific gravity	0.9099 at 15°C.
Refractive index	1.522 at 20°C.

Nepeta ciliaris (VERN. *Zufa*)

There are a number of species of *Nepeta* which grow wild in Kashmir. These species are *Nepeta ciliaris, N. ruderalis* and *N. elliptica* and all are used medicinally here.

Nepeta ciliaris commonly grows at altitude between 6,000 to 7,000 ft. and a ***sharbet*** (syrup) made from leaves and seeds is given in coughs and fevers. The dried leaves and flowering tops were steam-distilled with results as shown in Table VIII.

TABLE VIII

Characteristics of the oil of Nepeta ciliaris

Yield of the oil	0.543 pe cent
Specific gravity	1.061 at 20°C.
Refractive index	1.499 at 20°C.

Nepeta ruderalis

It grows in Kashmir on the road side and is used in the treatment of fever and gonorrheoea. The dried leaves and flowering tops were steam-distilled but only traces of oil were obtained.

The dried roots of *Iris kumaoneneis* (vern. *Krisham*) and *Iris kashmiriana* growing wild in Kashmir and reputed for their aromatic properties were also steam-distilled but only traces of the essential oil were obtained.

The dried bark of *Betula utilis* (vern. *Bhojpattra*) and the dried leaves and flowering tops of *Plectranthus regosus* (vern. *Pumar*) which also grow wild and are reputed for their aromatic properties gave on steam-distillation only traces of oil.

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PLANT QUARANTINE NOTIFICATION

Notification No. F. 16-5/44-A. dated the 3rd December 1945 of the Government of India in the Department of Agriculture.

In exercise of the powers conferred by Sub-section (1) of Section 3 of the Destructive Insects and Pests Act, 1914 (II of 1914), the Central Government is pleased to direct that the following further amendment shall be made in the order published with the notification of the Government of India in the late Department of Education, Health and Lands, No. F. 320/35-A., dated the 20th July 1936, namely :

In sub-paragraph (1) of paragraph 14 of the said order, for the words 'Kathiawar port' the words 'port of Kathiawar, or of the Lasbela or Kalat State' shall be substituted.

THE MAYNARD GANGA RAM PRIZE

APPLICATIONS are invited for the award of the Maynard Ganga Ram Prize of Rs. 3,000 for a discovery or an invention or a new practical method which will tend to increase agricultural production in the Punjab on paying basis. The prize is open to all, irrespective of caste, creed or nationality and Government servants are also eligible for it. Essays and theses are not accepted. The prize will be awarded for something practically achieved as a result of work done after the prize was founded in 1925. Competitors in their applications must give a clear account of the history of their invention or discovery and must produce clear evidence that it is the result of their own work. In the case of an improved crop details of parentage, evolution and history and a botanical description are necessary.

The Managing Committee reserves to itself the right of withholding or postponing the prize if no satisfactory achievement is reported to it, or to reduce the amount of the prize or to divide it if the quality of the entries justify this decision.

Entries should reach the Director of Agriculture, Punjab, Lahore, not later than 31st October, 1946.

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The Editorial Committee of the Imperial Council of Agricultural Research, India, takes no responsibility for the opinions expressed in this Journal

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